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STUDIES OF LAKES

AND WATERSHEDS

IN

MUSKOKA-HALIBURTON, ONTARIO:

METHODOLOGY (1976-1985)

Data Report Dr 86/4



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Water Resources Branch

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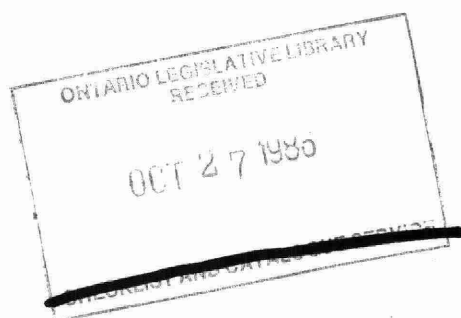
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**STUDIES OF LAKES AND WATERSHEDS
IN MUSKOKA-HALIBURTON, ONTARIO:
METHODOLOGY (1976-1985)**

B.A.Locke and L.D.Scott



DATA REPORT DR 86/4



PREFACE

The Data Report Series is intended as a readily available source of basic data collected for lakes and watersheds in the Muskoka/Haliburton area of Ontario. These data were collected as part of the Lakeshore Capacity Study and/or the Acid Precipitation in Ontario Study.

The limnological portion of the Lakeshore Capacity Study (1975-81) was initiated to investigate the relationships between lakeshore development and lake trophic status in low ionic strength Precambrian lakes. The Acid Precipitation in Ontario Study (1979-present) was initiated, in part, to investigate the effects of the deposition of strong acids on aquatic and terrestrial ecosystems in Ontario. The primary findings of these studies have been and will continue to be published as reviewed papers and technical reports.

Abstract

A summary of the analytical and field collection methods routinely employed by the Limnology Unit of the Ontario Ministry of the Environment at the Dorset Research Centre is presented. The methodology summary includes hydrological gauging, lake, stream, and precipitation chemical sampling, and biological sampling in the Muskoka-Haliburton study area during 1976-1985. A brief description of the analytical procedures used by the Laboratory Services Branch during 1976-1985 is also presented.

Locke, B.A. and L.D. Scott. 1986. Studies of lakes and watersheds in Muskoka-Haliburton, Ontario: Methodology (1976-1985). Ont. Min. Envir. Data Report DR 86/4.

Table of Contents

	<u>Page No.</u>
Introduction.....	1
Study Area.....	1
1. Meteorological Methods.....	3
i) Precipitation Collection Methods.....	3
ii) Precipitation Sampling for Chemical Analysis.....	5
iii) Meteorological Data Base.....	7
2. Stream Monitoring Methods.....	9
i) Watershed Delineation.....	9
ii) Stream Gauging Stations.....	9
iii) Instrumentation.....	13
iv) Discharge Measurements.....	15
v) Stream Sampling for Chemical Analysis.....	20
3. Limnological Methods.....	22
i) Station Location.....	22
ii) Lake Sampling for Chemical Analysis.....	22
a) Ice-free Period.....	22
b) Ice-cover Period.....	23
4. Biological Sampling Methods.....	28
i) Light, Phytoplankton and Chlorophyll.....	28
ii) Zooplankton.....	30
a) Regular Sampling.....	30
b) Non-routine Sampling.....	32
c) Enumeration of Regular Samples.....	33
5. Analytical Methods.....	39
i) Introduction.....	39
ii) Field Laboratory Location and Water Supply.....	39
iii) Field Sample Collection Methods.....	40
iv) Chemical Analysis Methodology Summary.....	43
v) Quality Assurance.....	73
References.....	75

Introduction

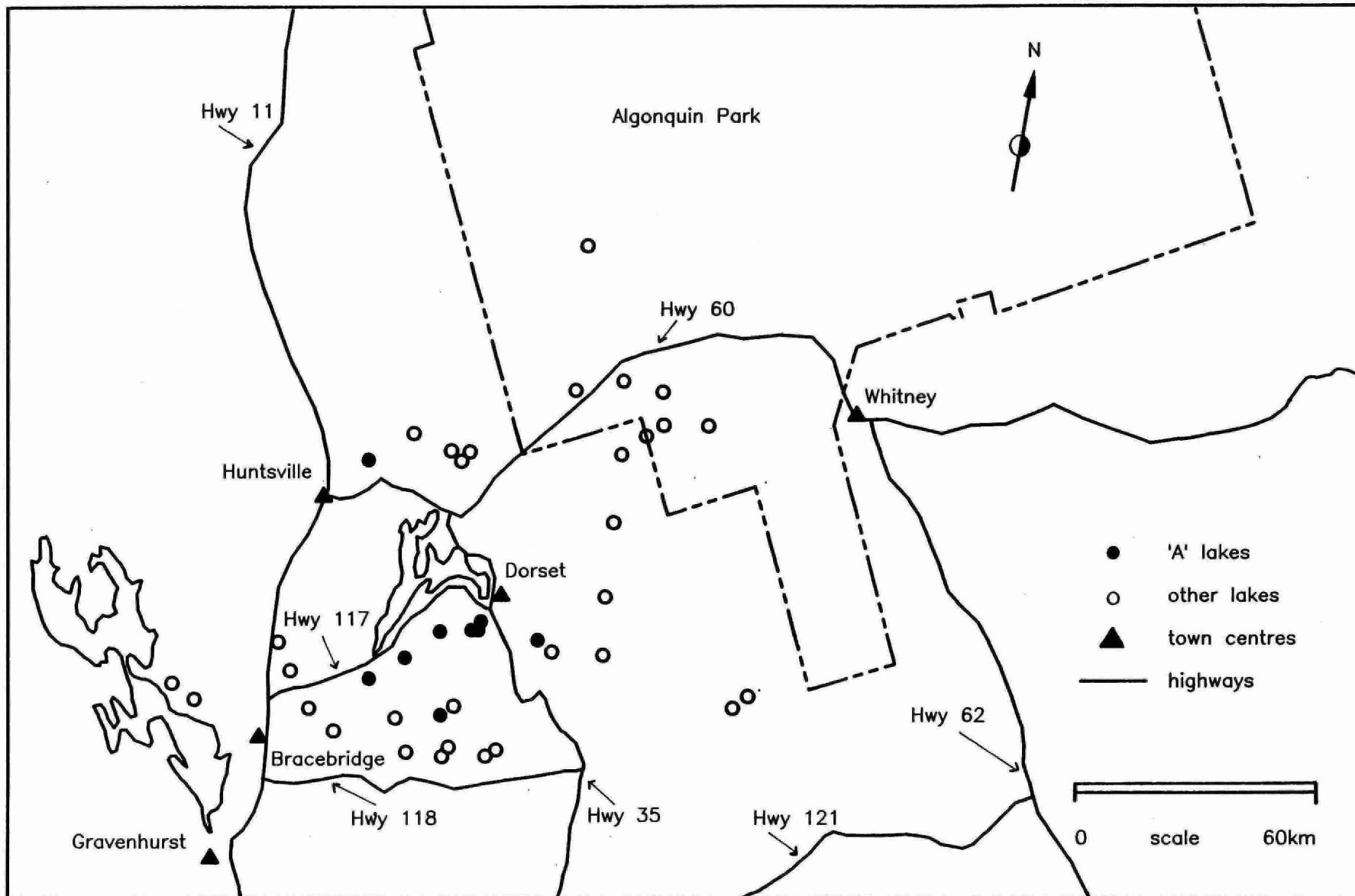
This report updates the field and laboratory methods used by Ontario Ministry of the Environment, Water Resources Branch, Limnology Unit, and summarized in Data Report DR 83/1 (Scheider et al. 1983). The studies described here were initiated as part of the Lakeshore Capacity Study (1975-1981) and continued as part of the Acidic Precipitation in Ontario Study (1979-ongoing). The APIOS programme rationale, objectives and areas of responsibility are described in Ontario Ministry of the Environment (1984).

In both programmes, representative sets of study lakes, catchments and precipitation collection sites were selected. The chemistry and biology of the lakes and streams were studied for a number of reasons, including the need to develop the capability to predict changes in ecosystem chemistry and biology as a result of anthropogenic stresses. The importance of establishing a long-term data base resulted in the continued study of the same sites from one programme to the other. Substantial efforts to maintain uniformity in methodology were made.

Study Area

The locations of the principal study lakes, streams and precipitation stations are shown in Figure 1, (reference UTM's and location I.D.#'s for all stations in Nicolls et al. 1986). Most lakes are underlain by Precambrian metamorphic silicate bedrock with thin Pleistocene glacial deposits. Glen Lake as well as Beech Lake Inlet 1, Twelve Mile Lake Inlet N and Twelve Mile Lake Inlet S are underlain by thick surficial deposits containing carbonate till. The area is forested with mixed deciduous-coniferous stands. A more detailed description of the geology of the area is given in Jeffries and Snyder (1983).

Figure 1. Map of Study Area



1. Meteorological Methods

i) Precipitation Collection

Both wet-only event and bulk precipitation collectors have been used to collect precipitation samples from 14 stations located throughout the study area from 1976 to 1980. Additionally, Environment Canada meteorological stations provided data used in the calculation of water balances of the study lakes and watersheds. The M.O.E. precipitation stations, along with their operation dates and gauge codes are listed in Table 1.

The Limnology Unit precipitation network was modified in 1980, at the beginning of the APIOS programme. Bulk collectors (some set up on rafts) were used at each site, with event collectors used at only the Dorset site and the Algonquin Park site. During the summer of 1982, the bulk samplers were moved from rafts on the lakes to nearby clearings on shore and use of all event samplers was discontinued, resulting in a total of five monitored stations. In the spring/summer change-over in 1984, three of the five stations (Harp, Plastic and Heney) were upgraded with Belfort rainfall depth gauges that transmit data to CR21 microloggers connected to Panasonic RQ 356 mini-cassette recorders. A precipitation and hydrometeorological network user guide summarizes the equipment and operational procedures currently used by the Limnology Unit (Locke and deGrosbois, 1986). A 2500 cm² square bulk sampler is still used as the precipitation chemical sampling device.

All collectors were placed approximately 1.67 m above ground (or maximum snow) level. Rainfall depths used in the calculation of deposition were measured at each site from 1976-1983 using a 10 cm standard rain gauge. From January 1984 to the present, Belfort rainfall gauges have been used. From January to June 1984, both methods of depth measurement were used for comparison.

Table 1. Precipitation station network used by the Limnology Unit.

M.O.E. Precipitation Station		Operation Dates	Gauge Codes*
HPP	Harp raft	76/08/13-82/11/16	0, 1, 9, 61, 62
HPP	Harp 3A	82/11/16-84/05/02	0, 1, 62
HPP2	Harp 4	84/01/07-present	3, 62
CLP	Clear lk. island	78/08/29-79/07/04	0, 1, 9, 62
ANB	Algonquin Airfield	78/05/09-80/05/20	0, 1, 9, 61, 62
ANB	Algonquin E. gate	80/06/02-84/09/30	0, 1, 9, 61, 62
VT	Vankoughnet	76/05/05-80/05/08	0, 1, 9, 61, 62
CNP	Crosson raft	80/05/08-82/11/16	0, 1, 9, 62
GFP	Gullfeather raft	76/07/30-78/11/08	0, 9, 62
CV	Carnarvon	76/08/16-79/01/24	0, 1, 9, 61, 62
EG	Eagle	76/08/17-80/05/02	0, 1, 9, 61, 62
PCP	Plastic raft	80/05/02-82/11/16	0, 1, 9, 62
PCP	Plastic gravel pit	82/11/18-84/10/30	0, 1, 62
PCP2	Plastic N shore	84/01/17-present	3, 62
A) PTIP	Dorset site	76/11/09-79/11/30	0, 1, 4, 61, 62
PT2	Dorset (Paint)	79/05/04-79/11/30	62
B) PTIP	Dorset site	79/11/30-82/11/17	0, 1, 9, 61, 62
PT2	Dorset (Micro)	79/11/30-82/11/17	62
C) PTIP	Dorset site	82/11/17-present	0, 1, 9, 62
PT2	Dorset (Bellwood)	82/11/17-84/05/02	62
RC	Red Chalk raft	76/08/03-78/11/02	0, 1, 9, 62
HYP	Heney - west	82/11/16-84/10/30	0, 1, 62
HYP2	Heney - east	84/01/10-present	3, 62

*Gauge Codes - (Sample Information System assigned):

- 0 Standard 10 cm rain gauge
- 1 Nipher snow gauge
- 3 Belfort rain gauge (also model 201 RH probe - hourly and daily relative humidity, temperature, daily vapourization pressure)
- 4 Snow ruler
- 9 Volume calculated from bucket (quality control flag)
- 61 Wet-only collector
- 62 2500 cm² square bulk collector

Snow depths used in deposition calculations were measured from 1976-1978 with a snow board and ruler. From 1978 to the present, snow samples were melted and volumes measured to obtain water equivalent depth, using either Nipher gauges (1978-1984) or Belfort gauges (1984-present). Calculation of the input of material to the lake from precipitation was carried out using a method similar to that described in Scheider et al. (1979b).

Snow surveys were carried out at selected sites in the Harp Lake, Plastic Lake, and Paint Lake catchments, and at the Dorset meteorological station in the winters of 1981-86 (Table 2). A Mount Rose or Utah sampler was used on some of the plots to measure snow depth, density and water equivalent. A 10 cm X 180 cm Plexiglass core tube was used to take snow cores for chemical analysis. Snow cores taken for chemical analysis were extruded into prewashed tubs in the field and covered with plastic bags. Sufficient cores were taken to provide 3-4 L of meltwater. The snow was melted (12-24 hr) in the laboratory at Dorset at room temperature and filtered through 102 μ m mesh before analysis (Scheider et al. 1984). During the winters of 1981/82 and 1982/83 there were six snow plots per snow course (about 50 m apart), located in areas representative to the basin. During the winters of 1983/84 and 1984/85 the snow cores were sampled from single plots located at the Paint Lake Inlet 1 and at the Dorset Meteorological Station. The results of these studies and detailed methodology employed are reported in Scheider et al. (1983) and Scheider et al. (1984). Atmospheric Environment Service (AES) is continuing to monitor snow accumulation and melt at two sites in the Dorset area.

ii) Precipitation Sampling for Chemical Analysis

Moisture-activated battery-operated samplers (Applied Earth Science Consultants, 929 cm² square) opened automatically during periods of precipitation and collected the 'wet' or event fraction of precipitation (1976-1982). One event sampler at the Dorset Station (1978-1982) was electrically heated for winter use. Snow samples were thus melted and kept in the liquid state.

Table 2. Summary of snow surveys carried out in Muskoka-Haliburton, 1981-1986

Site	Winter Period	Study Group ¹	Measurements	Equipment ²
Harp 3A	1981/82	1	density	a,b
	1982/83	1	"	a
Harp 4	1981/82	1	density, chemical	a,c
	1982/83	1	density	a
Harp 5	1981/82	1	"	a
	1982/83	1	"	a
Harp 6	1981/82	1	"	a
	1982/83	1	"	a
HPP Precip.	1982/83	1	chemical	c
HPP2	1983/84	1	"	c
Plastic A	1981/82	1	density, chemical	a,c
	1982/83	1	density	a
" B	1981/82	1	density, chemical	a,c
	1982/83	1	density	a
" C	1981/82	1	density, chemical	a,c
" D	1981/82	1	"	a,c
	1982/83	1	density	a
" E	1982/83	1	"	a
PCP Precip.	1982/83	1	chemical	c
PCP2 Precip.	1983/84	1	"	c
Paint 1	1981/82	1	density, chemical	a,c
	1982/83	1	density	a
	1984/85	2	chemistry, drip plot	c,d
	1985/86	2	"	c,d
Dorset Met.	1982/83	1	chemistry	c
Station	1983/84	1,2	chemistry, drip plot	c,d
	1984/85	2	"	c,d
	1985/86	2	"	c,d

¹1. Dorset Research Centre, Limnology

2. Atmospheric Environment Service, Climatology Section, Downsview, (Barry Goodison)

²a. 'Utah' snow sampler - for density measurements

b. 'Mount Rose' snow sampler - for density measurements

c. Plexiglass core tube (10 cm x 180 cm)

d. Snow drip plot with tipping bucket recorder and sampling notch

From Sept. 1976 to May, 1978, polyethylene funnels (30 cm opening) fastened to 250 L plastic containers were used to collect bulk deposition. Funnels were fitted with 500 μm Nitex mesh to prevent contamination by insects. Beginning in May, 1978, bulk deposition was collected with 0.25 m^2 square collectors with Teflon-coated, stainless-steel funnels leading into 18 L glass bottles (summer) or 43 cm diameter by 63 cm polyethylene containers (winter). The funnels were fitted with fibreglass window screening mesh to prevent contamination by insects.

Beginning in Nov. 1978, snow samples were obtained with the 0.25 m^2 Teflon-funnel collector, modified for winter use with a wider throat opening. Starting in May, 1983, 18 L polyethylene carboys were used in place of the glass bottles for summer collection.

The bulk collectors were open at all times and thus collected both the wet and at least part of the dry fraction of the precipitation. Samples were removed from the collectors when there was sufficient volume for all chemical analyses. Collection periods ranged from 1 to 40 days (winter), most samples being collected weekly. Samples were filtered at the lab through 76 μm (1976-1982) or 102 μm (1982-present) Nitex mesh to remove coarse particulates, and any that were obviously contaminated were discarded. The specifics of the parameters analyzed and lab analytical techniques are described in Section 5.

iii) Meteorological Data Base

A meteorological data base consisting of daily or hourly records for a variety of weather-related parameters measured in the Muskoka-Haliburton area has been established. The data are obtained from the source groups on magnetic computer tape; the records are re-formatted into station and parameter-specific files.

This data base provides a comprehensive source of meteorological information for evaporation and heat budget modelling. A user manual is available for reference (Locke and deGrosbois, 1986).

2. Stream Monitoring Methods

i) Watershed Delineation:

Boundaries of all lakes and watersheds were delineated by stereoscopic interpretation of air photos. Where interpretation was difficult, the boundaries were checked by field observation. More accurate delineation using field survey methods is in progress and will be described in a subsequent report.

ii) Stream Gauging Stations:

Stream gauging sites were selected with the objective of measuring total stream flow at a point as close to the lake as possible. Factors influencing the choice of sites included: presence of impermeable material, stream gradient, accessibility, and ease of construction of hydrologic control sites.

Station design was governed by maximum and minimum expected flows. Estimates of maximum and minimum stage flows were determined by level surveying from a static level (zero flow) to the high water-mark and supplemented by information given by local residents. Once maximum and minimum stage (water levels) were established, reference was made to tables showing design and size specifications of weirs or flumes (Leupold and Stevens 1975, Dept. of the Interior 1975).

Weirs or flumes (Table 3) were installed (1976-1977) on 21 inlet streams and 6 outlet streams of the original 6 study lakes. Additional structures were installed on 9 streams entering non-calibrated lakes ("export" streams). Creosote-treated plywood to which 8 mil plastic was attached with asphalt cement was used to construct the weirs. Although this type of design performed adequately, many minor problems such as leakage, flexing of the structure, station insensitivity to flow changes, and damage by rodents and weathering, indicated a need for a more permanent structure. Improvements to the weirs and flumes began in 1979 and were completed by 1981. New

Table 3: Description of hydrological gauging stations on 6 original study lakes (Blue Chalk, Chub, Dickie, Harp, Jerry and Red Chalk), 3 new study lakes (Crosson, Heney and Plastic), and "export" streams.

Stream	Structure	Period of Operation
Blue Chalk 1	. Combination 22½° and 90° V-notch weir	June 1976-Nov. 1979
	. 90° V-notch weir	Nov. 1980-present
	. Heated Dome	Nov. 1982-present
Blue Chalk Outflow	. H flume 183 cm wide flume with low flow structure	Sept. 1976-Aug. 1980
		Nov. 1980-present
Chub 1	. 90° V-notch weir	June 1976-Aug. 1980
	. 90° V-notch weir	Nov. 1980-present
	. Heated Dome	Nov. 1982-present
Chub 2	. Cippoletti weir	June 1976-Sept. 1976
	. Cippoletti weir with 120° V-notch	Sept. 1976-Mar. 1977
	. Cippoletti weir	Mar. 1977-Aug. 1977
	. Cippoletti weir with low flow structure	Aug. 1977-Sept. 1980
	. 91 cm wide flume with low flow structure	Sept. 1981-present
	. Heated Dome	Nov. 1982-present
Chub Outflow	. 120° V-notch weir	May 1976-Sept. 1980
	. 152 cm wide flume with low flow structure	Nov. 1980-present
Crosson 1	. 244 cm wide flume with low flow structure	Aug. 1981-present
Crosson Outflow	. 244 cm wide flume with low flow structure	Dec. 1980-present
Dickie 5	. 90° V-notch weir	Aug. 1976-May 1977
	. Combination 90° V-notch and rectangular weir	May 1977-Nov. 1980
	. 91 cm wide flume with low flow structure	June 1981-present
	. Heated Dome	Nov. 1982-present
Dickie 6	. 90° V-notch weir	Aug. 1976-June 1979
	. 90° V-notch weir	June 1979-present
	. Heated Dome	Nov. 1982-present
Dickie 8	. H flume	Aug. 1976-June 1979
	. H flume with 90° V-notch weir as downstream control	June 1979-July 1981
	. H flume with rectangular weir as downstream control	July 1981-present
	. Heated Dome	Nov. 1982-present
Dickie 10	. 90° V-notch weir	Aug. 1976-June 1977
	. Combination 90° V-notch and rectangular weir	June 1977-June 1979
	. Combination 90° V-notch and rectangular weir	June 1979-present
	. Heated Dome	Nov. 1982-present
Dickie 11	. 120° V-notch weir with downstream H flume	Aug. 1976-June 1979
	. 120° V-notch weir	Aug. 1979-present
	. Heated Dome	Nov. 1982-present

Table 3 (cont'd)

Stream	Structure	Period of Operation
Dickie Outflow	. H flume	Aug. 1976-June 1977
	. H flume and downstream low flow structure (90° V-notch)	June 1977-Apr. 1979
	. H flume and downstream low flow structure (90° V-notch)	Aug. 1979-present
Harp 3	. 90° V-notch weir	June 1976-June 1977
	. 90° V-notch weir with upstream flume	June 1977-June 1979
	. 90° V-notch weir	June 1979-present
	. Heated Dome	Nov. 1982-present
Harp 3A	. 90° V-notch weir	June 1976-June 1977
	. 90° V-notch weir with H flume	June 1977-Sept. 1979
	. Combination 90° V-notch and rectangular weir	Sept. 1979-present
	. Heated Dome	Nov. 1982-present
Harp 4	. 90° V-notch weir	June 1975-Jan. 1980
	. 122 cm wide H flume with low flow structure	Feb. 1981-present
	. Heated Dome	Nov. 1982-present
Harp 5	. 91 cm wide H flume	Sept. 1976-Aug. 1979
	. 152 cm wide H flume with low flow structure	Aug. 1979-present
	. Heated Dome	Nov. 1982-present
Harp 6	. 90° V-notch weir	Sept. 1975-Oct. 1980
	. 90° V-notch weir	Feb. 1981-present
	. Heated Dome	Nov. 1982-present
Harp 6A	. 90° V-notch weir	June 1976-Aug. 1979
	. 90° V-notch weir	Feb. 1981-present
	. Heated Dome	Nov. 1982-present
Harp Outflow	. H flume	June 1976-Aug. 1979
	. 152 cm wide H flume with low flow structure	Aug. 1979-Apr. 1980
	. 305 cm wide H flume with low flow structure	Feb. 1981-present
Heney Outflow	. 152 cm wide flume with low flow structure	Sept. 1981-present
	. Heated Dome	Nov. 1982-present
Jerry 1	. 90° V-notch weir	Sept. 1976-June 1980
Jerry 3	. No structure	
Jerry 4	. Combination 90° V-notch and rectangular weir	Sept. 1976-June 1980
Jerry Outflow	. H flume	Aug. 1976-June 1980
Plastic 1	. Combination 90° V-notch and rectangular weir	Sept. 1979-present
	. Heated Dome	Nov. 1982-present
Plastic Outflow	. 91 cm wide flume with low flow structure	Sept. 1979-present
	. Heated Dome	Nov. 1982-present
Red Chalk 1	. 90° V-notch weir	June 1976-Apr. 1980
	. 122 cm wide flume with low flow structure	Sept. 1980-present
	. Heated Dome	Nov. 1982-present

Table 3 (cont'd)

Stream	Structure	Period of Operation
Red Chalk 2	. 90° V-notch weir	June 1976-Sept.1980
	. 90° V-notch weir	Nov. 1980-present
	. Heated Dome	Nov. 1982-present
Red Chalk 3	. 120° V-notch weir	July 1976-June 1978
	. 120° V-notch weir	June 1978-Sept.1980
	. 122 cm wide flume with low flow structure	Sept.1981-present
	. Heated Dome	Nov. 1982-present
Red Chalk 4	. 120° V-notch weir	June 1976-Sept.1980
	. 91 cm wide flume	Sept.1981-present
	. Heated Dome	Nov. 1982-present
Red Chalk Outflow	. 120° V-notch weir	Jan. 1976-Nov. 1976
	. 266 cm wide H flume	Nov. 1976-June 1977
	. 266 cm wide H flume with low flow structure	June 1977-July 1979
	. 244 cm wide H flume with low flow structure	Sept.1979-present
<u>"Export" Streams</u>		
Haliburton Lake Inlet 12	. 120° V-notch weir	June 1977-June 1980
Moose Lake Inlet 1	. 244 cm wide H flume	Sept.1976-June 1977
	. 122 cm wide H flume	June 1977-June 1980
Twelve Mile North	. H flume	July 1976-Sept.1980
	. 152 cm wide flume with low flow structure	Dec. 1980-present
	. Heated Dome	Nov. 1982-present
Twelve Mile South	. 120° V-notch weir	Aug. 1976-Oct. 1980
	. Combination 120° V-notch and rectangular weir	Dec. 1980-present
	. Heated Dome	Nov. 1982-present
Paint Lake Inlet 1	. 90° V-notch weir	June 1976-Aug. 1981
	. 90° V-notch weir	Sept.1981-present
	. Heated Dome	Nov. 1982-present
Trading Bay Inlet 1	. 90° V-notch weir	Apr. 1976-June 1980
Duck Lake Inlet 1	. 90° V-notch weir	July 1976-June 1980
Head Lake Inlet 1	. 90° V-notch weir	Sept.1977-June 1980
Beech Lake Inlet 1	. 120° V-notch weir	Sept.1976-Oct. 1980
	. 213 cm wide flume with low flow structure	Dec. 1980-present
	. Heated Dome	Nov. 1982-present

structures were installed on 20 major inlet streams and 8 outlet streams on 5 of the original 6 lakes plus 3 new study lakes. Stations were also installed on 4 of the "export" streams (Table 3). The new structural design incorporated steel-reinforced concrete bases and walls situated on impervious material. Stations were rated to handle maximum flows two times greater than flows previously recorded. Incorporation of rectangular or 'V' notches into the control throat, established sensitivity through all stages of the hydrograph (Figure 2).

iii) Instrumentation

Stage (water level) is recorded both continuously and measured instantaneously at regular intervals. Instantaneous stage is read from 2 porcelain-coated metal staff gauges located in the weir basin. Continuous stage is recorded with a Leupold and Stevens type 'A' Model 71 float-operated recorder. As a reference check to the observed instantaneous stage height, metric calibrated tapes were installed on the recorders in 1982 and set to a stage height corresponding to the weir basin gauge. Cold-weather operation of selected sites (1976- 1978) was made possible by heating stilling wells with oil-fueled burners. Winter operation of the entire network commenced in 1979 with the aid of catalytic propane heaters. Continuous stage monitoring was improved in 1982 with the placing of heated covers over 25 weir basins.

Recorder charts are changed every six months, coinciding with the hydrological year. Instrument maintenance (1976 to 1979) was performed on a need-only basis. Regularly scheduled maintenance programmes were implemented in 1979 and include:

- . level surveying of structure on a yearly basis,
- . inspection of staff gauges on a weekly basis,
- . recorder inspection on a weekly basis,
- . gauging site and basin inspection on a weekly basis, and
- . meter calibrations are updated on a yearly basis, or as required (at Canada Centre for Inland Waters, Burlington, Ontario).

HARP '4'

TOP VIEW

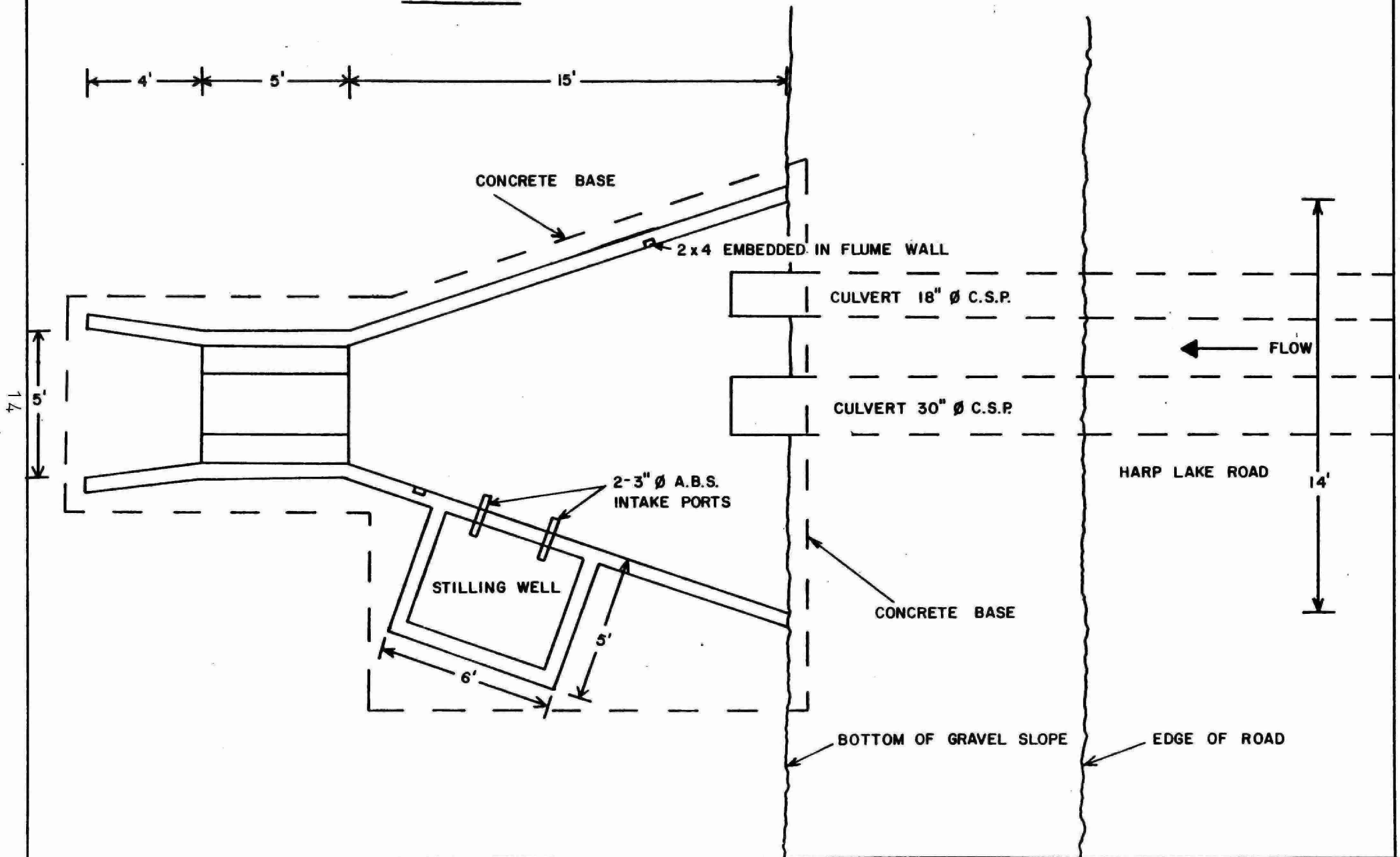


Figure 2. Sample structural design for stream gauging station (weir - HARP 4)

iv) Discharge Measurements

The theoretical stage-discharge relationship is, in most cases, different from the actual relationship. Each structure was therefore rated by measuring the discharge of water over the full range of stage height.

Discharge measurements were obtained by one of two methods depending on flow. At flows <8 L/sec, the entire volume of the stream was caught in a container for a measured period of time and discharge calculated. Measurements were taken in triplicate and then averaged.

Flows of >8 L/sec were calculated by combining the measured velocity of the water with the cross-sectional area of the stream. Velocity was measured using either a Teledyne Gurley Pygmy Model 625, an Ott C2 or an Ott C31 current meter. The C31 was found to be less accurate in the lower flows found in small head water streams and was not used after 1980. Electronic gauging equipment was tested in the fall of 1982. Results indicated that this type of equipment either was not sensitive enough to low flows, or was affected by the steel reinforcements in the cement. Stream discharges were defined (1976-1984) in natural cross-sectional areas, over 0.1 m or 0.2 m intervals. At each interval a total depth of water is measured with a metric ruler and a stream velocity is recorded at a depth 60% from the surface (Figure 3).

Flow velocity measurements made using the current meters have a minimum duration of 40 seconds. Permanently marked gauging sections were established by 1982, and cross-sectional intervals were defined and categorized as having either uniform flow or irregular flow. If flow through the section was uniform, i.e. without obstruction, then the maximum stream width was incremented into >5 and ≤ 20 intervals. Irregularities within the section such as backflow, eddies, and stream deflections require more measurements over the interval distance. Negative flows were measured by rotating the current meter 180 degrees

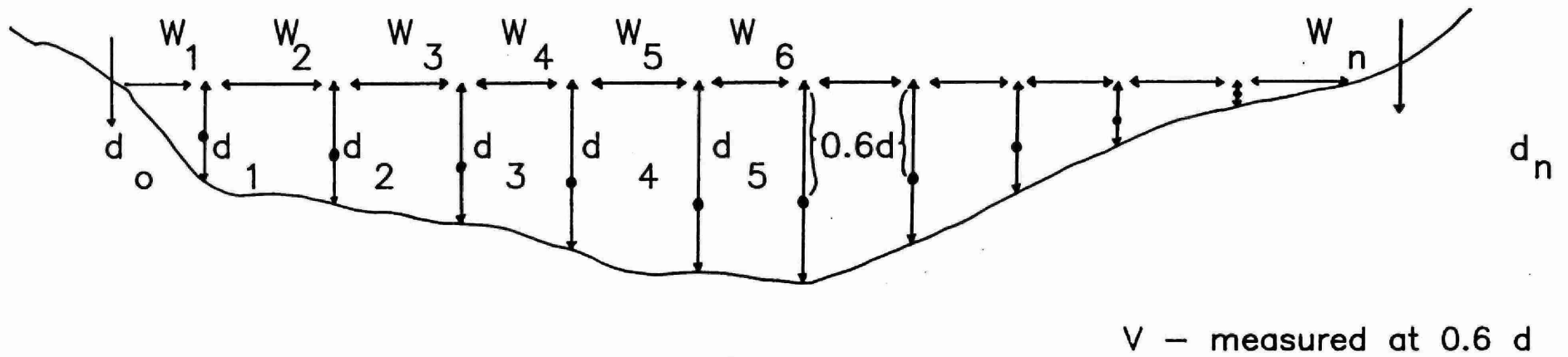
to the normal flow patterns. Propeller revolutions in excess of five per second affect counter accuracy. The pitch of the propeller should be selected commensurate with flow velocity. Discharge measurements were taken on each visit from 1976 to 1983. This frequency was reduced in 1983 and further in 1985, with the development of site-specific stage curves. These curves were divided into 3 sections representing discharges requiring monthly, bi-weekly and weekly monitoring. These divisions were dependent on the number of measurements within each range of the stage discharge relationship, i.e. the quality of the calibration curve in each range. Duplicate discharge measurements were made on each visit within the bi-weekly or weekly sections. A typical flow pattern that developed (such as those caused by debris in the user notch) warranted a discharge measurement.

Discharge was calculated from 1976 to May 1982 (Figure 3) using the mean section method. In May 1982 a modification to the computer programme permitted the subtraction of backflow from net discharge. Duplicate discharge calculations were carried out routinely.

Stage-discharge curves were established for each weir and flume for the periods 1976-1980 and 1980-1984 (Figures 4 and 5). Calculated zero head was subtracted from the observed stage readings and the actual stage was then plotted against measured discharge to derive a calibration curve. The continuous stage records were converted to continuous daily discharge using the 'STREAM' programme (Water Survey of Canada, 1977). Daily discharge was plotted as a continuous stream hydrograph. Data found to contain discrepancies was edited with the aid of site specific records and meteorologic information. Missing data were estimated by one of several available mathematical relationships (Scheider et al. 1983a).

Estimation of runoff from ungauged portions of the watershed was done on an individual lake basis. The measured runoff from the gauged catchments was areally weighted then pro-rated to estimate the ungauged portion of the total runoff.

Figure 3. Mean Section Method of calculating stream discharge



$$Q = \sum_{i=1}^n \frac{V_{i-1} + V_i}{2} \cdot \frac{d_{i-1} + d_i}{2} \cdot W_i$$

Q = stream discharge

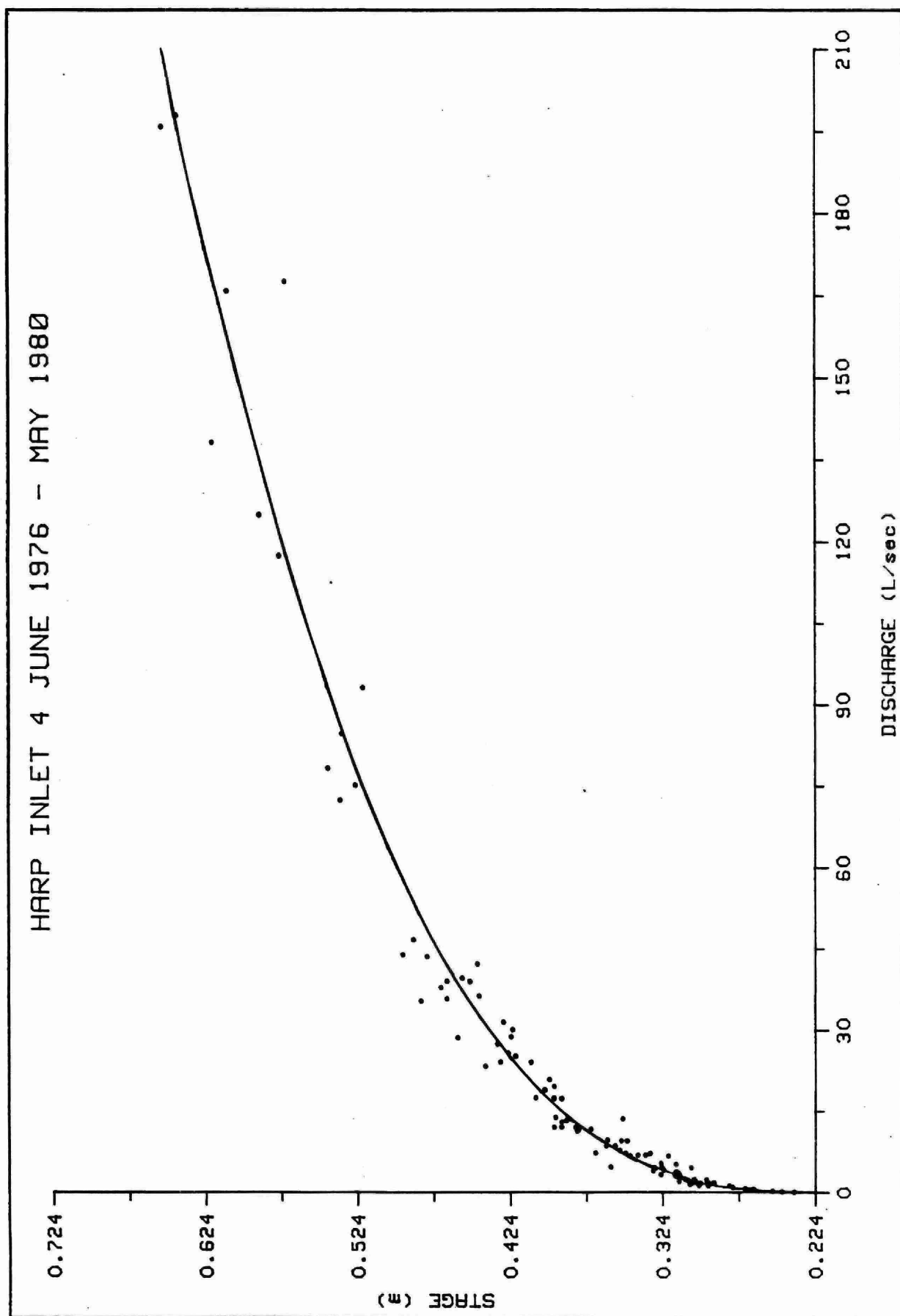
d = water depth

V = water velocity at 0.6 d

$V_0 = 0$ at edge of stream

w = distance between adjacent d,V measurements

Figure 4. Sample stage discharge curve for Harp 4 (1976-1980)



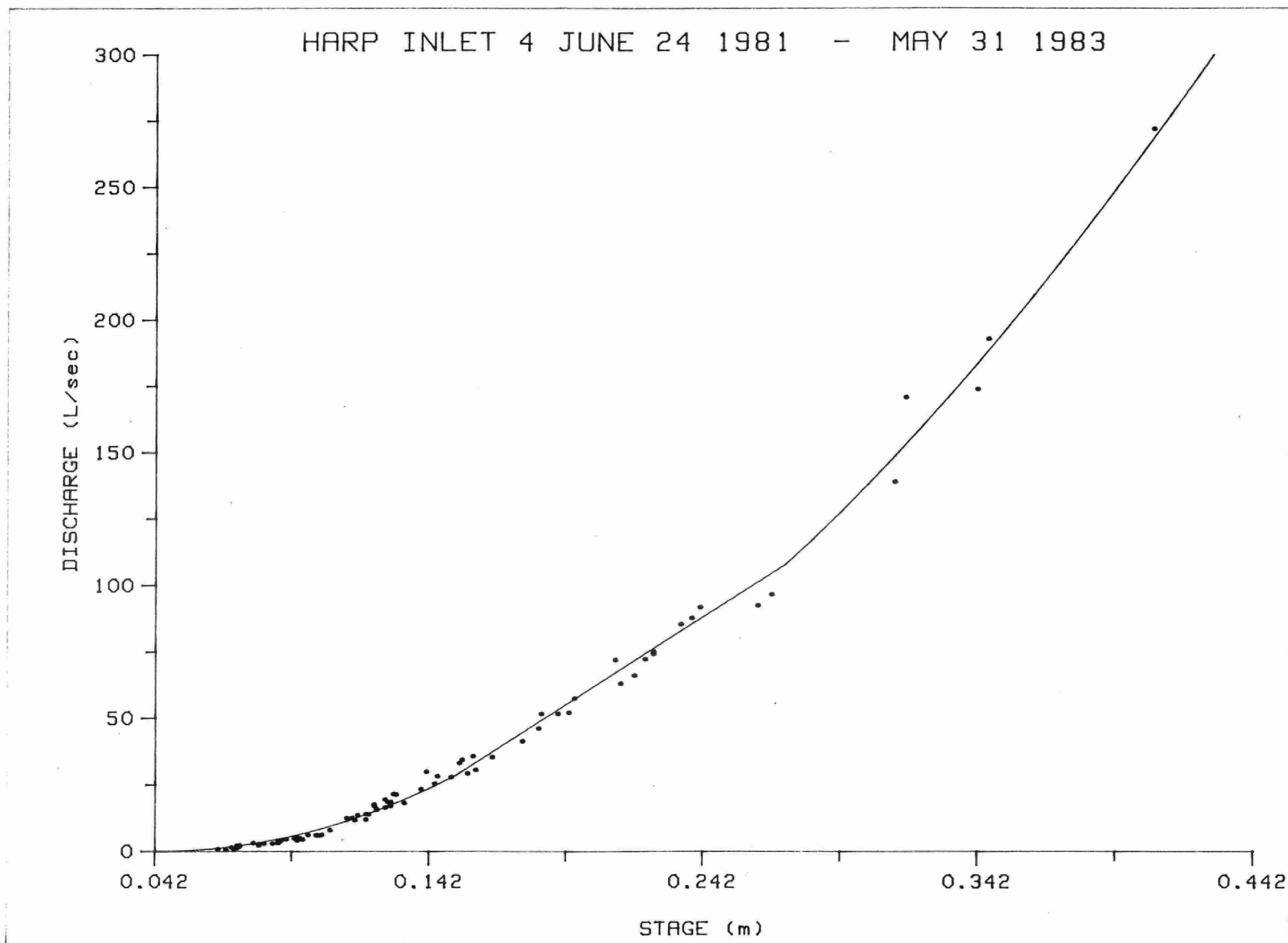


Figure 5. Sample stage discharge curve for HARP 4 (1981-1983)

Lake level gauges are used to calculate changes in lake storage over the hydrologic year (June 01-May 31). These gauges are permanently established and related to a Bench Mark (B.M.) using standard survey methods. Measurements are taken at weekly intervals during the ice-free period

Net evaporation rates (evaporation loss - condensation gain) for the ice-free period were calculated for each lake as the residual term in an energy balance equation (Scheider, 1983a). Details will be provided in an upcoming hydrology data report.

v) Stream Sampling for Chemical Analysis

From 1976 to 1980, samples were collected from the inflows and outflows of the 6 major study lakes once every two weeks during winter, as frequently as possible (>1/week) during the period of springmelt, and weekly during the remainder of the year. Inlet streams of 6 of the 9 minor study lakes were sampled monthly. Parameters analyzed and analytical techniques used were identical to those for lake water, except that analyses of DIC and O₂ were excluded and none of the biological parameters were measured.

Stream samples from 1976-1982 were collected once every two weeks during the winter, as frequently as possible (>1/week) during the period of springmelt, and weekly during the remainder of the year. Beginning in 1982, the inflows of Dickie and Harp Lake were sampled daily and the other 21 streams several times per week throughout springmelt. The 11 inflow streams of Harp and Dickie were sampled three times per week during the rest of the year and all other streams were sampled weekly.

Samples were filtered through 80 µm Nitex mesh into appropriate pre-rinsed sample bottles and were placed in a temperature-controlled container while in transit to the laboratories. Possible sources and causes of contamination of the sample (e.g. sticks, leaves, or grass, road oiling, calcium deposition, logging or construction) are documented in field log books.

The field sample collection procedures, specifics of parameters analyzed and analytical techniques are described in Section 5. All samples, excluding oxygen, were collected as grab samples at the point of control discharge. Dissolved oxygen is collected at a point upstream representative of normal stream flow.

Since May, 1982, all hydrological field work has been done by contractors. The methodology and quality assurance has been kept current and they are informed of any on-going changes as they occur.

3. Limnological Methods

Major study lakes ("A" lakes in Table 4) were monitored weekly (1976-1982) and bi-weekly (1982-present). The sampling frequency on all other lakes was monthly or bi-monthly. In 1982, 12 Algonquin-Haliburton lakes were added to the study as part of a joint OME/MNR special project. These lakes were sampled monthly during the ice-free season. In 1980, after the completion of the Sudbury Environmental Study, four of the Sudbury study lakes were added to the sampling schedule and were sampled monthly (bi-monthly during the ice-cover period). The locations of all study lakes are shown in Figure 1, and are identified in Table 4.

i) Station Location

Bathymetric maps were drawn at 2 m contour intervals from 20-30 sonar transects taken with a Furuno Mark III echo-sounder. Morphometric measurements were calculated using Hutchinson (1957). Selected morphometric data are summarized for routinely sampled study lakes in Table 5. Morphometric maps and more detailed data are given in Ontario Ministry of the Environment (1983), Nicolls et al. (1983), Reid et al. (1984) and Girard (1985).

All routine samples are collected at the deepest spot in each of the single-basin lakes and at the deepest spot in each of the two basins of Red Chalk, Cinder and Poker Lakes (Ontario Ministry of the Environment 1983).

ii) Lake Sampling for Chemical Analysis

a) Ice-free Period

Temperature of the lakes was measured at 1 m intervals to lake bottom (0.5 m intervals through the metalimnion) with a Montedoro-Whitney Model TC-5C thermistor (1976-March 1983), or a Flett Research Ltd. model Mark II digital telethermometer (March 1983-present). The depths of the epilimnion,

metalimnion and hypolimnion were calculated at the field site from the temperature vs depth plot (Wetzel, 1975). Yearly plots of the thickness of these strata in each lake are given in Reid (1983) and Reid and Girard (1985).

Samples for chemical analysis were taken with a Masterflex peristaltic pump using Tygon tubing (i.d. 9.5 mm) at 2 m intervals to lake bottom commencing at 1 m below surface. The hose was rinsed before sampling by pumping water through the length of tubing (15 m of Tygon tubing is approximately equal to 1000 ml). All sampling containers and carboys were rinsed a minimum of 3 times. An aliquot of water proportional to the volume of stratum represented was removed from each depth and added to an 8 L Nalgene carboy such that a single, volume-weighted, composite sample was obtained for each of the epilimnion, metalimnion and hypolimnion of the lake. Under conditions of thermal homogeneity, water from all depths was pooled to give a single, volume-weighted sample, representative of the entire lake. Separate samples were taken at 2 m intervals to the lake bottom for O₂, pH and DIC analyses. Annual profiles of these parameters are reported in Reid et al. (1983), Girard (1985), Reid et al. (1985a), and Reid et al. (1985b).

Appropriate sample containers (see Section 5) were filled by pouring the composite sample through 80 µm Nitex mesh to remove coarse particulate material. Samples were poured in the field and transported in temperature controlled containers to either the Dorset or Toronto laboratory, depending upon parameter.

b) Ice-cover Period

During the period of ice-cover, the "A" lakes were sampled monthly, the "B" lakes twice (1976-1982) and the Sudbury lakes monthly (1980-present). The sampling procedure was similar to that of the ice-free period with the following

exceptions. A measurement of snow and ice thickness was taken at the sampling site and subsequent sampling depths were measured from the ice surface. All holes through the ice surface were made by hand-auger to avoid contamination. Water was subsampled from the 8 L carboy at the Dorset laboratory or in the field, depending on the severity of the temperature.

: List and designation of study lakes

ation	Lake	Study Period	Ice-free Season Sampling 1 Frequency
A"	Blue Chalk	1976-present	a
	Chub	1976-present	a
	Crosson	1979-present	a
	Dickie	1976-present	a
	Harp	1976-present	a
	Heney	1979-present	a
	Jerry	1976-1980	a
	Plastic	1979-present	a
	Red Chalk-Main Basin	1976-present	a
	Red Chalk-East Basin	1977, 1980, 1982-present	a
"B"	Basshaunt	1976-present	b
	Bigwind	1976-present	b
	Buck	1976-present	b
	Crosson	1976-1979	b
	Glen	1976, 1978-present	b
	Gullfeather	1976-present	b
	Little Clear	1976-present	b
	Solitaire	1976-present	b
	Walker	1976-present	b
"C"	Axe	1979-1982	c
	Brandy	1979-present	c
	Cinder	1979-present	c
	Cinder-East Basin	1983-present	c
	Clear	1979-1983	c
	Fawn	1976-present	c
	Healey	1979-present	c
	Leech	1979-present	c
	Leonard	1979-present	c
	McKay	1979-present	c
	Moot	1979-present	c
	Poker	1979-present	c
	Poker-East Basin	1979-present	c
	Red Pine	1983-present	c
Sudbury	Clearwater	1973-present	b
	Hannah	1973-present	b
	Lohi	1973-present	b
	Middle	1973-present	b
Algonquin- Haliburton	Big Porcupine	1983-present	b
	Bonnechere	1983-present	b
	Clear	1983-present	b
	Crown	1983-present	b
	Delano	1982-present	b
	Kimball	1983-present	b
	Louisa	1981-present	b

Table 4 (cont'd)

Distination	Lake	Study Period	Ice-free Season Sampling ¹ Frequency
	Nunikani	1983-present	b
	Sherborne	1982-present	b
	Smoke	1981-present	b
	Timberwolfe	1982-present	b
	Westword	1981-present	b

¹ a. (1976-1982) weekly, (1982-present) bi-weekly

b. monthly

c. 6 times

Table 5: Summary of selected morphometric data for the study lakes

Lake	Area (ha)	Mean Depth (m)	Max. Depth (m)	Volume (m ³ x10 ⁵)
Blue Chalk	49.4	8.5	23	42.1
Chub	32.2	8.9	27	28.5
Crosson	56.8	8.4	25	47.7
Dickie	93.2	5.0	12	46.4
Harp	66.9	12.4	40	82.6
Heney	21.7	3.3	6	7.24
Plastic	32.3	8.0	17	25.8
Red Chalk - M	43.9	16.7	38	73.3
Red Chalk - E	13.0	5.73	19	7.46
Basshaunt	47.3	7.7	24	36.6
Bigwind	111	10.7	32	118
Buck	40.3	10.9	30	43.9
Glen	16.3	7.2	15	11.8
Gullfeather	65.9	4.8	13	31.5
Little Clear	10.9	8.1	25	8.86
Solitaire	124	13.3	31	164
Walker	68.2	6.2	17	42.1
Brandy	108	3.50	7.5	37.7
Cinder - W	26.9	4.76	16.0	12.82
Cinder - E	50.1	10.1	36.5	50.7
Fawn	85.8	3.52	7.9	30.2
Healey	122	2.77	7.0	33.7
Leech	82.0	6.33	13.7	51.9
Leonard	195	6.89	15.2	134
McKay	122	5.23	19.5	63.5
Moot	46.2	2.68	7.9	12.4
Poker - W	15.3	6.26	17.5	9.61
Poker - E	5.42	6.85	20.5	3.72
Clearwater	76.5	8.3	21.5	64.2
Hannah	27.3	4.0	8.5	10.8
Lohi	40.5	6.2	19.5	25.0
Middle	28.2	6.2	15.0	17.5
Big Porcupine	235	7.5	30.5	177
Bonnechere	105	6.4	21.4	67.0
Clear	88.4	12.4	33.0	109
Crown	136	8.0	30.0	108
Delano	23.9	7.1	18.6	17.0
Kimball	213	22.0	61.0	464
Louisa	513	16.1	61.0	856
Nunikani	116	7.9	24.0	91.7
Sherborne	252	9.6	35.1	241
Smoke	679	16.2	55.0	1099
Timberwolfe	167	7.4	20.4	124
Westword	63.3	20.5	44.4	129

4. Biological Sampling Methods

i) Light, Phytoplankton and Chlorophyll

From 1976-1982, the euphotic zone was estimated as twice the Secchi disc depth. In 1982, and 1983 light profiles were measured in each lake during the ice-free season using a Li-Cor Model 185 light meter equipped with a Li-192 cosine-corrected quantum sensor. Measurements were taken immediately above and below the surface and at depths of 0.5 m, 1 m, 2 m, etc. until light was undetectable. The lower limit of the euphotic zone was considered to be the depth where light was 1% of the readings taken just below the surface (0.05m or JBS). This estimated depth closely approximated twice the Secchi depth on most lakes. From the 1984 ice-free season, to the present date, the euphotic zone was estimated as twice the Secchi disc depth. The Secchi disc was lowered on the shaded side of the boat through the water column until it disappeared from view. The viewer should be ~40 cm from the water surface. The depth at which the Secchi disc disappears from view was noted and multiplied by 2. During the ice-cover period the euphotic zone was uniformly estimated as the upper 6m.

Beginning May, 1982 a profile of photosynthetically active radiation (PAR) was recorded on selected lakes. An "in-water" surface reference, a down-welling and an up-welling radiation component was measured ($\mu\text{ES}^{-1}\text{m}^{-2}$). The three cosine-corrected model L1-192 SB flat sensors were attached to a model SS-3 selector by means of sensor specific calconnectors. The sensor selector was then attached to a model L1-188B Integrating Quantum Radiometer Photometer. The "in-water" reference sensor was kept in a constant position, immersed in the lake and receiving solar radiation. The two profile sensors were permanently fastened on a model L1-2009S lowering frame directing the sensors in opposing directions on a vertical axis. Measurements were integrated for 10 seconds on the three sensors simultaneously at each interval of the profile. The profile increment was constructed so that a minimum of seven

intervals were measured. In lakes of shallow depth or inhibited light penetration (either for reasons of turbidity or colour) the profile increment was set at half-metre intervals from 0.05 m (or JBS), to the depth where 1% of the JBS light level was measured. In lakes of deep light penetration, the increment was set at JBS, 0.5 m, 1.0 m, 2.0 m and alternating metres 4, 6, 8, etc. thereafter until the depth where 1% of JBS light was measured. Supplementary intervals were added on occasions where euphotic sample depth (2 X Secchi disc) exceeded that of 1% of the JBS light measurement. The 1% of JBS was derived from a measurement of down-welling at a depth with a corresponding reference value to that of the initial JBS (0.05 m) measurement. In the event of changing light at the reference sensor, all other measurements were correspondingly corrected. When the euphotic zone derived from the calculation of twice the Secchi disc depth differed from that of 1% of JBS light on Chub, Plastic and Red Chalk Lake (main basin) in 1983 - 1985, separate collections were made for each euphotic zone.

Collection of samples for analysis of chlorophyll and phytoplankton was identical to that for chemical analysis except that all samples were collected volumetrically from the euphotic zone. All phytoplankton samples were unfiltered, volumetrically combined, and preserved with 1-3 ml of Lugol's preservative in a 1 L glass bottle. The samples were shipped to the Aquatic Biology Unit of the Ministry of the Environment for analysis. Occasionally, live phytoplankton samples were submitted for identification. These samples were collected in the same manner as outlined above, but were not preserved and were refrigerated until shipped to Toronto.

The chlorophyll samples were collected in 1 L opaque plastic bottles, which were refrigerated until submission for analysis. At the laboratory in Dorset, each chlorophyll sample was shaken and then the preservative added. From 1976 to Sept. 1980, 10 drops (~1.0 mL) of 10% $MgCO_3$ solution was added. After September 1980, 0.5 mL of 10% $MgCO_3$ was used. A measured volume (500-1000 mL) was vacuum (5-10 psi) filtered through a

1.2 μm Sartorius or Millipore filter paper. On June 1, 1985, Ultipor nylon filters of the same pore size replaced the filters used to that date. The filters were then frozen in Petri dishes covered in aluminum foil and sent to Toronto for analysis. Additional samples for chlorophyll analysis were taken at odd-metre intervals on Plastic Lake for each of the dates on which Schindler/Patalas trap zooplankton profiles were measured, throughout the 1985 ice-off period.

Phytoplankton were counted on inverted microscopes by the Utermohl method (Utermohl, 1958). In the Utermohl technique, subsamples of the concentrated samples were settled into 2.1 or 5.0 mL Utermohl-type plankton counting chambers. At least one half of the chamber was scanned at 150X for larger phytoplankters. One to several radii were examined at 600X for smaller forms. Between 200 and 400 'units' (cells, filaments or colonies) were counted for each sample (Lune *et al.* 1958). Nicholls and Carney (1979) list the classical monographs which were routinely employed for identifying the phytoplankton. Dimensions of all counted cells, excluding gelatinous envelopes and chrysophyte loricae were recorded and volumes computed by calculating volumes of most similar geometric shapes. Volumetric data were converted to biomass (as wet weight), assuming unit density.

ii) Zooplankton

a) Regular Sampling

From 1976 to May 1978, zooplankton samples were collected with a 30 L Schindler/Patalas trap (S/P), equipped with 76 μm mesh (Schindler 1969). Samples were collected at odd metre intervals from a depth of 1m to 1m above bottom at the deepest point in each lake. The two distinct basins of Red Chalk Lake were treated as two lakes. Appropriate aliquots from each collection were subsequently pooled to produce a volume-weighted composite for enumeration.

In May 1978, the flow meter portion (with an attached 76 μ m net) of a Clarke-Bumpus sampler (C/B) replaced the S/P traps as the principle sampling gear. The tow net sampler was hauled vertically from pre-determined depths to the surface and contents of all hauls were pooled prior to analysis. The depths of each haul (Table 6) were chosen so that the contents of each haul contributed a volume-weighted portion to the final composite.

From 1980 to present, samples were collected during the ice-free season only. Numbers of samples collected from 1980 to 1985 are indicated in Table 7. The "A" lakes were sampled weekly in 1980 and 1981, and bi-weekly thereafter. None of the other study lakes were sampled in 1980. Beginning in 1981, these other lakes were generally sampled on a monthly basis.

All samples were preserved in the field in sugar-formalin solution. The concentration varied somewhat (2-4%) from year to year.

From 1978 to 1980, C/B sample volumes were calculated using a conversion factor of 5.6 L of lake water filtered per metre revolution. This figure was supplied by Dr. C. Bil of the National Water Research Institute in Burlington, Ontario, after calibrating the C/B sampler. From 1981 and onward, filtration efficiencies and sample volumes were determined as follows.

If: Sum C	= Sum of counter revolutions for all non-calibration hauls
Sum T	= The total length (m) of all non-calibration hauls
Tow L	= The length (m) of the longest haul
Won C	= Counter revolutions for the single calibration haul assumed to have length = Tow L

then, the filtration efficiency (Ef in %) is defined by

$$Ef = 100 \cdot \frac{\text{Sum C}}{\text{Sum T}} \cdot \frac{\text{Tow L}}{\text{Won C}} \quad (1)$$

If the meter counts per unit length are identical in the calibration and non-calibration hauls, then Ef = 100%.

If: A_{net} = area of the mouth of the C/B sampler
= $117 \times 10^{-4} \text{ m}^2$

The volume of lake water from which organisms were collected (VL in litres).

$$VL = A_{\text{net}} \cdot \text{Sum T} \cdot Ef \quad (2)$$

After equalization of dimensions, substitution of the Ef value from equation 1 and simplification this reduces to the working formula used, namely,

$$VL = 11.7 \cdot \text{Sum C} \cdot \text{Tow L/Won C}$$

The major difference between the new and old methods for calculating VL was the assumption of unvarying metre performance in the old method.

b) Non-routine sampling

Extra zooplankton samples were collected for a variety of reasons. Chub, Plastic and Red Chalk Lakes were sampled weekly during the ice-free seasons of 1980-1982 using the S/P trap equipped with 80 (1980), 35 (1981,)and 55 (1982) μm mesh. Separate composites were formed of epi-, meta- and hypolimnetic samples, so that distribution of organisms with depth could be calculated. The 1981 sampling programme using the 35 μm mesh was designed to provide quantitative rotifer data.

Spatial patchiness was assessed by collecting zooplankton at 5 widely-spaced stations in the epi- and metalimnion of Red Chalk Lake on 11 occasions in 1981. Results of this comparison are summarized in Yan (1986). In 1985, Chub and Plastic Lakes were sampled on a monthly basis with the S/P trap (80 μ m mesh) to examine the distribution of organisms with depth in clear (Plastic) and coloured (Chub) lakes. Also in 1985, volume-weighted and unweighted sampling strategies were compared by collecting three vertical metered hauls from 1 m above bottom in Plastic Lake in addition to the regular sample collection. Finally, we collected large amounts of zooplankton from Chub and Harp Lakes on a monthly basis in 1985. These samples were collected with a 150 μ m mesh net with a 0.75 m² surface area. These samples were frozen prior to contaminant analysis.

c) Enumeration of Regular Samples

The basic taxonomic reference routinely employed for identifying crustacean zooplankton was Edmundson (1959). Other references followed included Brooks (1957) as modified by Dodson (1981) for Daphnia, Korinek (1981) for Diaphanasoma, and Deevey and Deevey (1971) for Eubosmina. Rotifers were enumerated in some samples using Stemberger (1979) and Ahlstrom (1943). Immature copepods (nauplii and copepodids) were identified to the level of suborder in regular samples. A minimum of 250 crustaceans were enumerated in each sample giving a coefficient of variation ($V = 1/\sqrt{n}$) where n = number of animals on the estimate of crustacean density of 6%, assuming a Poisson distribution of the animals in the counting chambers.

Rotifer abundance was assigned a normal ranking of 0 to 5 (rare to very abundant) and dominant taxa were noted.

From 1976 to 1980, biomass was determined as follows. Weights of individual species were determined for all the dominant planktonic crustacea. 50-300 individuals (depending on their size) were chosen to represent all size classes observed in the year. These were removed from the samples and rinsed four times in distilled water to remove adhering preservative. They were placed on pre-weighed coverslips, dried to a constant weight (24 hr) at 80°C and weighed to the nearest tenth of a microgram on a Sartorius electro-balance. Separate dry weights were obtained for naupliar, copepodid and adult copepods. Weights employed are presented by Hitchin and Yan (1983).

For samples collected after 1980, a new method for counting zooplankton was used. An image of the subsample was displayed on a high resolution black and white video monitor. The length of each enumerated organism was measured on the monitor with calipers identical to those described by Sprules et al. (1981). The calipers were coupled electronically with a desk-top microprocessor. The dry weights of each enumerated organism were calculated using length-weight relationships for each species stored in the microprocessor (Sprules, unpub. data). The basic data generated on each sample therefore, included species compositions, relative abundance and biomass of species and a size spectra of the plankton.

Zooplankton data were routinely reported as density (animals/volume) or were converted to biomass using the determined weights. Because the sampling frequency was not always constant, averages of data for the ice-free season were determined by integration of density or biomass vs time plots (i.e. averages were time weighted). Additional details on zooplankton methods may be found in Hitchin and Yan (1980).

The non-regular samples were enumerated in manners consistent with the purpose of the specific sampling programme.

Table 6: Lengths (from the stated depth to the surface) and numbers (in parentheses) of vertical hauls, used to form composite samples for enumeration in the Dorset Lakes after May 1978. The volume filtered (assuming 100% filtration efficiency) is indicated.

Lake	Length (m)				Volume (L)
A. Blue Chalk	20(1)	15(1)	9(1)	4(2)	509.3
Chub	20(1)	15(1)	9(1)	4(2)	509.3
Crosson	19(1)	14(1)	9(1)	4(2)	489.7
Dickie	8(1)	6(1)	4(1)	2(1)	108.8
Harp	30(1)	21(1)	13(1)	6(2)	744.4
Heney	4(3)				117.5
Plastic	15(1)	11(1)	7(1)	3(1)	352.6
Red Chalk - Main	32(1)	24(1)	16(1)	8(1)	783.5
Red Chalk - East	15(1)	11(1)	7(1)	3(1)	352.6
B. Basshaunt	19(1)	14(1)	9(1)	4(2)	489.7
Buck	20(1)	15(1)	10(1)	5(1)	489.7
Glen	12(1)	9(1)	6(1)	3(1)	293.8
Gullfeather	8(1)	6(1)	4(1)	2(1)	195.9
Bigwind	25(1)	18(1)	11(1)	5(2)	626.8
Little Clear	12(1)	9(1)	6(1)	3(1)	293.8
Solitaire	27(1)	20(1)	13(1)	6(2)	705.2
Walker	10(1)	7(1)	4.5(1)	2(2)	250.3
C. Axe	12(1)				117.5
Brandy	4(2)				78.4
Cinder	18.5(1)	9.5(1)	5.75(1)	3.75(1) 3(1) 2(1)	416.8
Fawn	6.5(1)	2.75(1)	2(1)		109.9
Healey	5.5(1)	4(1)	3(1)	1.75(1) 1(1)	149.1
Moot	4.75(1)	4(1)	2(1)	1(1)	115.4
McKay	10.5(1)	5.5(1)	3.75(1)	1.5(1)	207.9
Poker - West	11.5(1)	7.5(1)	4.5(1)	1.75(1)	247.0
Leonard	15(1)	10(1)	5(1)		293.8
Leech	11.5(1)	9.5(1)	6.75(1)	4.75(1) 4(1) 1.5(1)	372.2
Red Pine	35(1)				342.8

Table 6: (Cont'd)

Lake	Length (m)					Vol (L)		
<u>Algonquin Lakes</u>								
Smoke	50(1)	30(1)	16(2)	8(2)	1253.7			
Westward	40(1)	30(1)	20(1)	10(1)	979.4			
Delano	15(1)	13(1)	8(1)	4(2)	430.9			
Timberwolf	19(1)	14(1)	9(1)	4(2)	489.7			
Louisa	50(1)	30(1)	16(2)	8(2)	1253.7			
Clear	30(1)	22(1)	14(1)	6(2)	763.9			
Tim	19(1)	13(1)	7(1)	3(1)	411.4			
Bonnechere	14.5(1)	10.5(1)	6.5(1)	3.75(1)	3(1) 1(2)	393.9		
Sherborne	23(1)	16.5(1)	15(1)	9(1)	6(1) 3.75(1)	3(1)	746.5	
Kimball	49(1)	35(1)	27(1)	19.5(1)	13.5(1)	7.5(1)	3(1)	1513.7
Crown	21.75(1)	16.5(1)	15(1)	8.25(1)	6(1)	3(1)	691.0	
Nunikani	17.5(1)	13(1)	9.5(1)	5(1)	4(1)	2(1)	499.0	
Big Porcupine	19.5(1)	12.5(1)	8.5(1)	5.75 (1)	3.75(1)	3(1)	2(1)	538.7
<u>Sudbury Lakes</u>								
Middle	13(1)	10(1)	6(1)	3(1)	313.4			
Hannah	7.5(1)	6(1)	4(1)	2(1)	191.5			
Lohi	18(1)	10(1)	6(1)	3(1)	362.4			
Clearwater	20(1)	13(1)	8(1)	4(1)	440.7			

Table 7: Number of crustacean zooplankton samples collected each year in the study lakes

Lake	Ice-free Season					
	1980	1981	1982	1983	1984	1985
A. Blue Chalk	16	20	14	13	13	13
Chub	15	21	14	14	14	12
Crosson	16	17	15	14	13	14
Dickie	16	18	15	13	12	13
Harp	13	21	15	12	13	14
Heney	15	12	-*	14	12	13
Plastic	16	19	14	14	13	14
Red Chalk - main	17	20	15	12	13	14
Red Chalk - east	0	0	0	13	13	13
B. Basshaunt	1	4	5	4	5	6
Bigwind	2	5	7	5	6	7
Buck	1	4	6	5	6	6
Glen	1	5	5	5	5	6
Gullfeather	2	4	8	5	7	7
Little Clear	1	4	6	5	6	6
Solitaire	1	4	7	5	6	6
Walker	1	3	6	4	6	6
C. Axe	0	4	2	0	0	0
Brandy	0	3	3	3	5	0
Cinder - west	0	4	0	3	5	0
- east	0	0	0	0	6	0
Fawn	0	4	2	3	4	0
Healey	0	5	0	3	4	0
Leonard	0	4	3	3	5	0
Leech	0	5	0	3	4	0
Moot	0	4	0	3	5	0
McKay	0	4	3	3	5	0
Poker - west	0	4	0	3	5	0
- east	0	0	0	0	4	0
Red Pine	0	5	3	0	0	0

TABLE 7: (Cont'd)

Lake	1981	Ice-free Season			
		1982	1983	1984	1985
<u>Algonquin Lakes</u>					
Big Porcupine	0	0	5	7	6
Bonnechere	0	0	5	7	6
Clear	4	6	5	6	6
Crown	0	0	7	7	6
Delano	0	5	5	7	6
Kimball	0	0	6	7	6
Louisa	7	7	5	5	6
Nunikani	0	0	4	7	6
Sherborne	0	4	5	7	6
Smoke	7	7	6	6	6
Tim	0	4	0	0	0
Timberwolf	0	7	6	7	6
Westword	7	6	7	7	6
<u>Sudbury Lakes</u>					
Clearwater	6	6	6	8	6
Hannah	6	6	5	8	6
Lohi	6	6	6	8	6
Middle	6	7	6	8	6
Swan **	7	10	10	12	12

*Sampled on a bi-weekly basis by S/P trap, all others by C/B tow net

**Samples collected by Bill Keller, M.O.E., Sudbury

5. Analytical Methodology Summary

i) Introduction

This section briefly lists the procedures used by the Limnology Unit for sample collection and by the Laboratory Services Branch for chemical analysis by parameter.

ii) Field Laboratory Location and Water Supply

The field lab site has been in three locations since the beginning of the study. From June 1975 to September 1976 two 12'x50' mobile trailers were located at the Vankoughnet site (corner of highway 118 and Clear Lake Rd., Oakley Twp.). These two trailers were moved to the Paint Lake site in September 1976, where they remained until December 1981. During this period (September 1980) an additional 12'x60' trailer was added to the site.

In January 1982, the new Dorset Research Centre, located on Bellwood Acres Rd. and highway 117 was opened. The site at that time contained two new 12'x60' mobile chemistry lab trailers, the three trailers from the Paint Lake site, a mobile trailer from the LCS microbiology study, a trailer from the Sudbury Environment Study, and two aquatic toxicity trailers. Over the next few years the facilities have been augmented by additions for office space, computer terminals, M.O.E. terrestrial studies, M.O.E. Air Quality, MNR, and various university groups. The field lab quarters for the hydrology, precipitation and lake crews were re-located several times and these changes have been documented. Currently there are 22 mobile laboratory facilities, encompassing roughly 17,000 ft² in area.

At the Vankoughnet field lab, deionized water was obtained by processing water from the Black River through a reverse osmosis module system. Additional distilled water for sample bottle preparation was shipped to the field lab site from the Toronto Water Quality lab.

When the field operations were moved to the Paint Lake site, deionized water for use in the lab was obtained from treatment of the lake water by the same reverse osmosis module system. The lake water was brought into the lab by PVC conduit directly from the lake. A well was dug on the new Bellwood Acres site in the fall of 1981. After six days of operation in January 1982, soil contamination from the bottom was evident and use of the well was discontinued. From February 3, 1982 through January 26, 1983, distilled water was shipped to Dorset from Crystal Springs Distillers and the W.Q. lab in Toronto in 45 gallon drums (50 in total). Conductivity checks were run on every barrel and those data kept for reference. On January 26, 1983 the new water supply system to the chemistry lab became operational. Water was pumped from Paint Lake to storage tanks, from where it is then pumped to all mobile labs. During the summer of 1982 the site holding tank was installed, and severe problems with iron-reducing bacteria became apparent. In the spring of 1983 all water lines were swabbed with iodine and filled with a chlorine-base solution. The lines were then purged until the background water chemistry was within acceptable levels. Regular weekly water analyses were used to verify lab water quality. Beginning in the spring of 1983, and continuing until the present time, additions of iodine to the holding tank on a varying weekly schedule were introduced to maintain good water quality.

On January 26, 1983 a reverse osmosis unit was installed and has produced all deionized water for laboratory and field crew use to present day. The mobile Laboratory Services Chemistry Section continues to use a R.O. system to supply deionized water for its operations.

iii) Field Sample Collection Methods

The sample container types and analytical methods are under continual revision. One of the most notable changes has been the shift away from field laboratory prewashing of reusable sample containers to single-use recyclable or throw-away

containers. The latter were routinely in use for the majority of parameters after June 1, 1982. All chemistry samples continue to be filtered in the field through 76 μ mesh. Analytical procedures, instrumentation and quality assurance and control methods have been outlined most recently as the 1982-1984 Performance Report from the Water Quality Section (D85001). Table 8 outlines the parameters tested as part of the Limnology Unit's studies.

Table 8: Parameters requested as part of the Limnology Unit's studies.

Abbrev.	Parameter Description	Reported Units
ACDT	Mineral Acidity	mg/L
ALKT	Total Fixed End Point Alkalinity	"
ALKT3	Total Fixed End Point Alkalinity (pH 3.8)	"
ALKTI	Total Inflection Point Alkalinity (pH 4.5)	"
ALDCV	Catechol-Violet Dialized Aluminum	µg/L
ALNDCV	Catechol-Violet Non-dialized Aluminum	"
ALEXCV	Extracted Catechol-Violet Dialized Aluminum	"
ALUT	Total Aluminum	"
CAUR	Calcium	mg/L
CCUT	Total Carbon (Approximated by DOC <20 mg/L)	"
CDUT	Cadmium	µg/L
CHLRBT	Chlorophyll b	"
CHLRAT	Chlorophyll a	"
CHLRAC	Chlorophyll a, corrected	"
CLIDUR	Chloride	mg/L
COLAP	Apparent Colour	Hazen units
COLTR	True Colour	True Colour Units
COND25	Conductivity at 25°C	µmhos/cm
CUUT	Copper	mg/L
DO	Dissolved Oxygen	"
DOC	Dissolved Organic Carbon	"
DIC	Dissolved Inorganic Carbon	"
FEUT	Iron	"
FFIDUR	Fluoride	µg/L
KKUR	Potassium	mg/L
MGUR	Magnesium	"
MNUT	Manganese	"
NAUR	Sodium	"
NIUT	Nickel	"
NNHTFR	Ammonium as N	µg/L
NNOTFR	Nitrate and Nitrite as N	"
NNTKFR	Filtered Kjeldahl Nitrogen (DKN)	"
NNTKUR	Total Kjeldahl Nitrogen (TKN)	"
PBUT	Lead	mg/L
pF	Free Fluoride	dimensionless
pH	pH	"
PPFT	Total Dissolved Phosphorus	µg/L
PPUT	Total Phosphorus	"
SI03UR	Silicates as SiO ₂	mg/L
SS04UR	Sulphate as SO ₄	"
ZNUT	Zinc	µg/L

iv) Chemical Analysis Methodology Summary

The following summary itemizes a brief chronological description for each parameter (or group of parameters) listed alphabetically. The sample type and analytical laboratory are used to subdivide each section, and include a synopsis of sampling containers, field collection and analytical methods.

Acidity - Total Fixed Endpoint (TFE)

Identification: ACDT, mg/L as CaCO_3

Sample type: precipitation

1. Laboratory: Dorset lab, Dorset, August 16, 1982-present
- Sampling: Container - 250 ml opaque brown nalgene, distilled water rinsed between samples
- Field collection - 76 μ mesh filter to May 1983, then 102 μ , triple rinse, refrigeration until analysis, no preservation
- Analysis: Separate filtration from ALKT and ALKTI, 0.01 N sodium hydroxide to pH endpoint of 8.3 standardized against 0.005 N potassium hydrogen phthalate
- Note: acidities have also been calculated, but not reported, from negative ALKTI results

Alkalinity - Total Fixed Endpoint (TFE)

Identification: ALKT, mg/L as CaCO₃

Sample type: streams, lakes

1. Laboratory: River lab, Toronto (W.Q. section), June 1975-July 26, 1979
Sampling: Container - 1 L Boston glass (new each sample, re-ground recycling)
Field collection - 76 μ mesh filtered sample poured directly into bottle after triple rinse and submitted for analysis
- no preservation, samples kept refrigerated
Analysis: Titration with 0.02 N sulphuric acid to a pH endpoint of 4.5
2. Laboratory: Dorset lab, Dorset, (lab services), July 26, 1979-June 1, 1982
Sampling: Container - 250 ml glass stoppered reagent bottle (distilled water rinse between samples)
Field collection - 76 μ mesh filter, triple rinse with sample, refrigeration until analysis, no preservation
Analysis: Done at room temperature, as above
3. Laboratory: Dorset lab, Dorset, June 1, 1982-present
Sampling: Container - 250 ml brown opaque nalgene, gas cap
Field collection - 76 μ mesh filter, triple rinse, refrigeration until analysis, no preservation
Analysis: As above for July 26, 1979-June 1, 1982

Sample type: Precipitation

1. Laboratory: River lab, Toronto, June 1975-April 1, 1978
Precipitation lab, Toronto, April 1, 1978-October 10, 1982
Sampling: Container - July 26, 1979-June 1, 1982, 1 L Boston glass
- June 1, 1982-October 10, 1982, 450 ml polystyrene
Field collection - as above
Analysis: As above
2. Laboratory: Dorset lab, Dorset, October 10, 1982-present
Sampling: Container - 250 ml opaque brown nalgene, gas cap, distilled water rinse between samples
Field collection - as above
Analysis: As above

Alkalinity - Total Fixed Endpoint to pH 3.8

Identification: ALKT3, mg/L as CaCO_3 -

Sample type: streams, lakes, precipitation

1. Laboratory: Dorset lab, Dorset, October 21, 1985-present
- Sampling: Container - 250 ml brown opaque nalgene, gas cap
 Field Collection - as above
- Analysis: Titration with 0.02N sulphuric acid to a pH endpoint
 of 3.8.

Alkalinity - Total Inflection Point (TIP), Gran

Identification: ALKTI, mg/L as CaCO_3

Sample type: streams, lakes, precipitation

1. Laboratory: Dorset lab, Dorset, July 26, 1979-June 1, 1982
Sampling: Container - 250 ml glass-stoppered reagent bottle,
distilled water rinse between samples
Field Collection - 76 μ mesh filter, triple rinse,
refrigeration until analysis, no
preservation
Analysis: Titration with 0.02 N sulphuric acid to pH <4.0 at a
delivery rate determined from the slope of the titra-
tion curve and pH stability. End point determined
potentiometrically using GRAN analysis of titration
data.
2. Laboratory: Dorset lab, Dorset, June 1, 1982-present
Sampling: Container - 250 ml opaque brown nalgene, distilled
water rinsed between samples
Field collection - as above
Analysis: As above

Aluminum

Identification: ALUT (total aluminum) in $\mu\text{g/L}$ or mg/L as Al

Sample type: streams, lakes, precipitation

1. Laboratory: Inorganic Trace Contaminants (ITC), Toronto, September 1976-May 1978
Sampling: Container - 500 ml or 1 L nitric acid washed nalgene (by Central Stores in Toronto)
Field collection - 76 μ filter, triple rinse with sample, preserved with 1 ml HNO_3 , non-refrigerated until analysis
Analysis: Graphite furnace atomic absorption
2. Laboratory: ITC, Toronto, May 1978-May, 1979
Sampling: Container - as above, storage prior to use filled with distilled water and fixed with 1 ml HNO_3
Field collection - as above
Analysis: As above
3. Laboratory: ITC, Toronto, May 1979-June 1, 1982
Sampling: Container - 500 ml nitric acid washed nalgene (by Central Stores in Toronto, no other pre-rinse)
Field collection - as above
Analysis: As above
4. Laboratory: ITC, Toronto, June 1, 1982-August 10, 1982
Sampling: Container - 250 ml polystyrene, plastic cap with no liner, rinsed with 5% Hcl and stored with 5% Hcl until use
Field collection - as above, preservation with .5 ml HNO_3 (Aristar)
Analysis: As above
5. Laboratory: ITC, Toronto, August 10, 1982-April 11, 1983
Sampling: Container - 250 ml or 450 ml polystyrene, plastic cap with no liner, new recycled each sample, no special rinse
Field collection - as above
Analysis: As above
6. Laboratory: Dorset lab, Dorset, April 11, 1983-present
Sampling: Container - 15 ml polypropylene centrifuge tube with cap, pre-leached in 1% CONC HNO_3 then rinsed 4 times with double de-ionized water
Field collection - as above, aliquot poured from 450 ml polystyrene into 15 ml centrifuge tube by lab after August 29, 1984
Analysis: Acidification to approximately 0.2% with ultraclean Aristar acid and refrigeration until analysis by graphite furnace atomic absorption.

Aluminum speciation

Identification: ALDSE (dialized aluminum) in $\mu\text{g/L}$ as Al
ALNDSE (non-dialized aluminum) in $\mu\text{g/L}$ as Al

Sample type: streams (routine + multistation), lakes routine + Sudbury)

1. Laboratory: Dorset lab, Dorset, April 11, 1983-August 29, 1984
Sampling: Container - 450 ml polystyrene, non-pulp lined cap
Field collection - 76 μ filter, triple rinse, separation into speciation sample containers by chemistry lab
Analysis: Short extraction method, ALNDSE by using buffered 8-hydroxyquinoline and methyl isobutyl ketone (MIBK), ALDSE from a dialysis sac filled with double deionized water and equilibrated in sample for 22 hrs (± 2 hrs).

Sample type: Plastic Multistation, Sudbury Lakes

1. Laboratory: Dorset lab, Dorset, August 29, 1984-October 15, 1985
Sampling: Container - as above
Field collection - as above
Analysis: As above

Identification: ALDCV (dialized catechol-violet reactive aluminum)
 $\mu\text{g/L}$ as Al inorganic monomeric Aluminum
ALNDCV (non-dialized catechol-violet reactive aluminum) $\mu\text{g/L}$ as Al, equal to ALDCV + ALEXCV
ALEXCV (extractable catechol-violet reactive aluminum)

Sample type: multistation streams, Sudbury lakes

1. Laboratory: Dorset lab, October 15, 1985-present
Sampling: Container - 450 ml polystyrene, plastic cap with no liner
Field Collection - 76 μ filter, triple rinse with sample, refrigeration until analysis
Analysis: Automated ion-exchange

Cadmium

Identification: CDUT in $\mu\text{g/L}$ or mg/L as Cd

Sample type: streams, lakes, precipitation

1. Laboratory: ITC (Inorganic Trace Contaminants), Toronto, June 1975 to Nov. 18, 1985...see Trace Metals
- Sampling: Container - 500 ml or 1 L nalgene, pre-acid rinsed and bagged
- Field Collection - 76 μ filter, triple rinse
- Analysis: Samples opened under clean air and acidified to 0.2% with 2 ml Superpure Nitric Acid. They are then rebagged and kept refrigerated until analysis by traditional graphite furnace atomic absorption spectrophotometry.

Sample type: Sudbury Lakes, precipitation, multistation streams and Harp streams

1. Laboratory: Dorset lab, Dorset, Nov. 18, 1985-present
- Sampling: Container - as above
- Field Collection - as above
- Analysis: As above, but reported in $\mu\text{g/L}$

Cations - Calcium, Potassium, Magnesium, Sodium

Identification: CAUR in mg/L as Ca
KKUR " K
MGUR " Mg
NAUR " Na

Sample type: streams, lakes, precipitation

1. Laboratory: River lab, Toronto, June 1975-present
Precipitation lab, Toronto, May 17, 1979-present
(detection limits lower in Precipitation lab)
- Sampling: Container - June 1975-June 1, 1982, 1 L Boston glass
- June 1, 1982-present, 450 ml polystyrene
Field collection - 76 μ filter, triple rinse, no
preservation except for refrigeration
- Analysis: CAUR - Atomic Absorption Spectrophotometry at 422.7 nm
using air-acetylene flame, acidified lanthanum
chloride added as a releasing agent
KKUR - Atomic Absorption Spectrophotometry at 766.5 nm
using air-acetylene flame, cesium chloride is
added as a suppressant
MGUR - Atomic Absorption Spectrophotometry at 285.2 nm
using air-acetylene flame, acidified lanthanum
chloride added as a releasing agent
NAUR - Atomic Absorption Spectrophotometry at 589.0 nm
using air-acetylene flame, cesium chloride is
added as a suppressant for lakes and streams
samples, potassium chloride for precipitation
samples
On Feb 27, 1984, the analytical range was adjusted
from 0.3-20 mg/L to 0.02 to 5.00 mg/L.

Chloride

Identification: CLIDUR, mg/L as Cl

Sample type: streams, lakes

- Laboratory: River lab, Toronto, June 1975-present
1. Sampling: Container - June 1975-June 1, 1982, 1 L Boston glass
Field collection - 76 μ filter, triple rinse, refrigeration until analysis, no preservation
- Analysis: June 1975-June 23, 1980 - Mercuric thiocyanate colourimetry
June 23, 1980-present - Automated suppressed ion chromatography
2. Sampling: Container - June 1, 1982-present - 450 ml polystyrene
Field collection - as above
- Analysis: Automated suppressed ion chromatography

Sample type: Precipitation

- Laboratory: River lab, Toronto, June 1975-April 1, 1978
Precipitation lab, Toronto, April 1, 1978-present
1. Sampling: Container - June 1975-June 1, 1982 - 1 L Boston glass
Field collection - 76 μ filter, triple rinse, refrigeration until analysis, no preservation
- Analysis: June 1975-June 23, 1980 - Mercuric thiocyanate colourimetry
June 23, 1980-present - Automated suppressed ion chromatography
2. Sampling: Container - June 1, 1982-present, 450 ml polystyrene
Field collection - as above
- Analysis: Automated suppressed ion chromatography

Chlorophyll

Identification: CHLRAT (chlorophyll a) in $\mu\text{g/L}$
CHLRBT (chlorophyll b) "
CHLRAC (acidified a) "

Sample type: lakes

Laboratory: River lab, Toronto, June 1975-present

1. Sampling: Container - 1 L opaque brown nalgene, specific containers for each station
Field collection - June 1975-June, 1985, no field filtration, triple rinse with sample, refrigeration in the dark until submission for analysis. Sample was preserved with 20 drops (1.0 ml) of 10% magnesium carbonate solution until September 1980, then 0.5 ml after that. A measured volume was filtered at the Dorset lab through a $1.2 \mu\text{m}$ cellulose nitrate membrane filter under moderate suction. The filter was then placed in a light-free container and frozen until submission to the River lab in Toronto

Analysis: A microcomputer-controlled automated spectrophotometer was used with two scans developed with absorbance measurements at 630, 645 and 665 nm. After automated acidification, chlorophyll a corrected can be calculated. SCOR-UNESCO equations are used for all chlorophyll calculations.

2. Sampling: Container - as above
Field Collection - Nylon filters replaced the sartorius filters used by the field chemistry lab in Dorset, June 17, 1985. All other methods remained the same.

Analysis: As above

Colour

Identification: COLAP (apparent colour), hazen units

Sample type: streams, lakes

1. Laboratory: River lab, Toronto, June 1975-September 1976
Sampling: Container - 1 L Boston glass, new recycled each sample
Field collection - 76 μ filter, rinse three times, refrigeration until analysis, no preservative
Analysis: Comparator disc technique, includes dissolved substances
2. Laboratory: Dorset lab, Dorset, September 1976-October 30, 1980
Sampling: Container - 1 L nalgene, acid/base washed and distilled water rinsed
Field collection - as above
Analysis: As above

Identification: COLTR (true colour), true colour units

Sample type: streams, lakes

- Laboratory: Dorset lab, Dorset
1. Sampling: Container - October 1, 1980-June 1, 1982, 1 L nalgene, acid/base washed and distilled water rinsed
Field collection - as above
Analysis: Colourimetric measurement against acidified cobaliplate standards, after correction for residual turbidity
- Sampling: Container - June 1, 1982-present, 450 ml polystyrene
Field collection - as above
Analysis: As above

Conductivity

Identification: COND25 in $\mu\text{mhos/cm}$ at 25°C

Sample type: streams, lakes, precipitation

1. Laboratory: River lab, Toronto, June 1975-June 1, 1982
Precipitation lab, Toronto, April 1, 1978-June 1, 1982
Sampling: Container - 1 L Boston glass
Field collection - 76 μ filter, triple rinse with sample, refrigeration until analysis, no preservatives added
Analysis: Conductivity meter, temperature controlled
2. Laboratory: Dorset lab, Dorset, May, 1977-June 1, 1982
Sampling: Container - 1 L nalgene, acid/base bath, distilled water rinse
Field collection - as above
Analysis: As above
3. Laboratory: Dorset lab, Dorset, June 1, 1982-present
Sampling: Container - 450 ml polystyrene
Field collection - as above
Analysis: As above

Dissolved Inorganic Carbon

Identification: DIC, mg/L as C, reported as TIC 1975-1978

Sample type: streams, lakes (strata samples), precipitation

1. Laboratory: River lab, Toronto, June 1975-June 3, 1980
Sampling: Container - 1 L Boston glass, new recycled each sample
Field collection - 76 μ filter, triple rinse, refrigeration in dark until analysis, no preservation
Analysis: Gas chromatography - bubble with carbon dioxide, sulphuric acid was added to generate gas, CO₂ was extracted through the column, conductivity bridge
2. Laboratory: Dorset lab, Dorset, June 3, 1980-present
Sampling: Container - 50 ml pyrex culture tube with screw-on gas cap, pre-labeled for each routinely sampled station
Field collection - as above, except for profile samples which are not filtered, field filtration of all other samples discontinued after March 25, 1986
Analysis: Automated colourimetric determination by auto analyser, phenylthaline indicator, H₂SO₄ to generate gas, CO₂ membrane used

Dissolved Organic Carbon

Identification: DOC, mg/L as C

Sample type: streams, lakes, precipitation

Laboratory: River lab, Toronto, June 1975-April 4, 1978

1. Sampling: Container - 1 L Boston glass
Field collection - 76 μ filter, triple rinse, refrigeration in dark until analysis, no preservation
- Analysis: Organic carbon component obtained by the difference between total carbon and the inorganic carbon. Total carbon is determined by injection of a known volume of sample onto a hot catalyst; the CO₂ gas produced on combustion is measured by infra-red spectrophotometry. Inorganic carbon is determined by acidifying a known volume in a closed chamber and the released CO₂ gas is measured by infra-red spectrophotometry.
2. Sampling: Container - April 4, 1978-June 1, 1982, 1 L Boston glass
June 1, 1982-present, 450 ml polystyrene
Field collection - as above
- Analysis: Automated, acidification and flushing with nitrogen gas to remove inorganic C. Organic carbon is oxidized to CO₂ by exposure to UV light in acid-persulphate media. Measurement by colourimetry with phenolphthalein.

Fluoride

1. Identification: FFIDUR in $\mu\text{g/L}$ as F

Sample type: streams, lakes, precipitation

Laboratory: Domestic Water, Toronto, April 11, 1983-April 1, 1986
Sampling: Container - 450 ml polystyrene with non-pulp lined cap
Field collection - 76 μ filter, triple rinse, no preservation, refrigeration until analysis
Analysis: Alizarin Blue colourimetry, free fluoride selective electrode (Orion)

2. Laboratory: Dorset lab, soils, April 1, 1986-present

Sampling: Container - as above
Field Collection
Analysis: Fluoride ion specific electrode, total ionic strength adjustment buffer containing phosphoric acid, sodium citrate, di-sodium EDTA, sodium chloride and sodium hydroxide to a pH 6.7. Automated system using Technicon Ion specific electrode module, (range = 0 to 70 $\mu\text{g/L}$).

3. Identification: pF (free Fluoride), negative logarithm

Sample Type: streams, lakes, precipitation

Laboratory: Dorset lab, Dorset, April 11, 1983-August 30, 1984, multistation streams and Sudbury lakes continue to be analysed to present
Sampling: Container - 450 ml polystyrene
Field collection - as above
Analysis: Done with Aluminum speciation process using an ion selective electrode

Iron

Identification: FEUT in mg/L as Fe

Sample type: streams, lakes, precipitation

Laboratory: River lab, Toronto, June 1975-October, 1979

1. Sampling: Container - June 1975-June 1, 1982, 1 L Boston glass
Field collection - 76 μ filter, triple rinse, refrigeration until analysis
- Analysis: Digestion and analysis colourimetrically by automated TPTZ method

Sample type: streams, lakes

Laboratory: River lab, Toronto, October, 1979-June 17, 1985

1. Sampling: Container - June 1, 1982-August 10, 1982, 250 ml polystyrene, rinsed with 5% Hcl and stored with Hcl, samples taken at this time preserved with 0.5 ml Aristar HNO₃
Field Collection - as above
- Analysis: As above
2. Sampling: Container - August 10, 1982-Nov 12, 1985, 450 ml polystyrene, no acid pre-rinsing or preservative
Field Collection - as above
- Analysis: As above
3. Sampling: Container - November 12, 1985-June 17, 1985 - 100 ml polystyrene vial, no preservative
Field Collection - as above
- Analysis: As above

Sample type: precipitation

Laboratory: Precipitation lab, Toronto, October 1979-June 17, 1985

1. Sampling: Container - October 1979-June 1, 1982, 1 L Boston glass
Field Collection - as above
- Analysis: Inductively coupled plasma using Argon, analysis by atomic emission spectrophotometry
2. Sampling: Container - June 1, 1982-Aug 10, 1982, 250 ml polystyrene, rinsed with 5% HCl and stored with HCl, samples preserved with 0.5 ml HNO₃
Field Collection - as above
- Analysis: As above
3. Sampling: Container - Aug. 10, 1982-Nov. 12, 1985 - 450 ml polystyrene, no acid pre-rinsing or preservative

Field Collection - as above
Analysis: As above
4. Sampling: Container - Nov. 12, 1985-June 17, 1985 - 100 ml
polystyrene vial, no preservative
Field Collection - as above
Analysis: As above

Sample type: streams, lakes, precipitation

Laboratory: ITC, Toronto, June 17, 1985-present
1. Sampling: Container - as above
Field Collection - as above
Analysis: Preconcentration with 0.5 ml 20% HNO₃, forced-air
convection oven overnight at 85°C ± 5°C, vials cooled
to room temperature and 2.5 ml Hcl added by Oxford
dispenser, determination by atomic absorption

Lead

Identification: PBUT in $\mu\text{g/L}$ or mg/L as Pb

1. Sample Type: streams, lakes, precipitation

Laboratory: ITC (Inorganic Trace Contaminants), Toronto, June 1975
to Nov 18, 1985
Sampling: see Trace Metals section
Analysis: Preconcentration and AAS (Flame) finish

2. Sample Type: Sudbury lakes, precipitation, multistation streams and Harp streams

Laboratory: Dorset lab, Dorset, Nov 18, 1985-present
Sampling: Container - 500 ml or 1 L nalgene, pre-acid rinsed and
bagged
Field Collection - 76 μ filter, triple rinse
Analysis: Graphite furnace atomic absorption spectrophotometry,
in $\mu\text{g/L}$

Manganese

Identification: MNUT in mg/L as Mn

Sample type: streams, lakes, precipitation

Laboratory: River lab, Toronto, June 1975-June 17, 1985

1. Sampling: Container - June 1975-April 1979, 1 L nalgene (acid washed), fixed HNO_3
Field collection - 76 μ filter, triple rinse
Analysis: Colourimetric determination by manganese-formaldehyde
2. Sampling: Container - April 1979-June 1982, 1 L Boston glass, no preservative
Field collection - as above
Analysis: As above
3. Sampling: Container - June 1982-August 10, 1982, 250 ml polystyrene, Hcl washed, fixed with 0.5 HNO_3
Field collection - as above
Analysis: As above
4. Sampling: Container - August 10, 1982-November 12, 1985, 450 ml polystyrene, preserved with HNO_3 for precip. samples only as submitted with rest of trace contaminants
Field collection - as above
Analysis: As above
5. Sampling: Container - Nov. 12, 1985-June 17, 1985, 100 ml polystyrene vial, no preservative
Field collection - as above
Analysis: As above

Laboratory: ITC, Toronto, Ontario, June 17, 1985-present

6. Sampling: Container - as above
Field Collection - as above
Analysis: Preconcentration in 0.5 ml 20% HNO_3 , dried overnight at $85^\circ\text{C} \pm 5^\circ\text{C}$, at room temp. 2.5 ml 5% Hcl added, determination by atomic absorption

Nitrogen

Identification: NNHTFR (ammonium plus ammonia) in $\mu\text{g/L}$ as N

Sample type: streams, lakes, precipitation

1. Laboratory: River lab, Toronto, June 1975-April 1, 1977
Sampling: Container - 1 L Boston glass
Field collection - 76 μ filter, triple rinse with sample, refrigeration until analysis, no preservation
Analysis: Ammonia plus ammonium ions are determined on the filtrate via the formation of indophenol blue in a buffered system using nitroprusside as a catalyst, colourimetric measurement through a 5.0 cm light path at 630 nm
2. Laboratory: Dorset lab, April 1977-August 1979
Sampling: Container - 125 ml prince of wales, acid/base bath then distilled water rinsed
Field collection - as above, but with filtration through Gelman .45 μ membrane filter
Analysis: Modified automated phenate-hydrochloride method with sodium nitro prusside
3. Laboratory: Dorset lab, August 1979-June 1, 1982
Sampling: Container - 500 ml or 1 L nalgene, acid/base bath then distilled water rinse
Field collection - as above, .45 μ filtration by chemistry lab
Analysis: As above
4. Laboratory: Dorset lab, Dorset, June 1, 1982-present
Sampling: Container - 450 ml polystyrene with non-pulp liner cap
Field collection - as above, lab filtration discontinued as of February 1, 1984
Analysis: As above

Identification: NNOTFR (nitrate plus nitrite) in $\mu\text{g/L}$ as N

Sample type: streams, lakes, precipitation

1. Laboratory: River lab, Toronto, June 1975-April, 1977
Sampling: Container - 1 L Boston glass
Field collection - 76 μ filter, triple rinse, refrigeration until analysis, no preservation
Analysis: Cadmium reduction, automated (deionization colourimetry method), reported in mg/L in some cases
2. Laboratory: Dorset lab, Dorset, April, 1977-August 1979
Sampling: Container - 125 ml prince of wales, acid/base bath, then distilled water rinse

- Field collection - as above but filtration through .45 μ membrane filters
- Analysis: Hydrazine reduction method, automated deazotization colourimetry
3. Laboratory: Dorset lab, Dorset, August 1979-June 1, 1982
- Sampling: Container - 500 ml or 1 L Nalgene, acid/base bath, then distilled water rinse
- Field collection - as above, but filtration by chemistry lab
- Analysis: As above
4. Laboratory: Dorset lab, Dorset, June 1, 1982-present
- Sampling: Container - 450 ml polystyrene with non-pulp lined cap
- Field collection - as above
- Analysis: As above, lab filtration discontinued February 1, 1984

Identification: NNTKFR (filtered Kjeldahl nitrogen), $\mu\text{g/L}$ as N

Sample type: streams, lakes, precipitation

1. Laboratory: Dorset lab, Dorset, Sept. 1976-June 15, 1979
- Sampling: Container - 125 ml prince of wales, acid/base bath, then distilled water rinse
- Field collection - 76 μ filter, then Gelman filtration through .45 μ membrane filters
- Analysis: Mod. Indophenol Blue method - block digestion

Identification: NNTKUR (total Kjeldahl nitrogen), $\mu\text{g/L}$ as N

2. Laboratory: River lab, Toronto, June 1975-Sept 1976
- Sampling: Container - 1 L Boston glass bottle
- Field collection - 76 μ filter, triple rinse, refrigeration
- Analysis: Persulphate digestion (hot plate)
3. Laboratory: Dorset lab, Dorset, Sept. 1979-Aug. 1979
- Sampling: Container - 125 ml prince of wales, acid/base bath, then distilled water rinse
- Field collection - as above
- Analysis: September 1976-May 2, 1977
- as above
- May 2, 1977-April 1, 1979
- Modified Indophenol Blue method (sodium nitropruside catalyst, AAI system)
- April 1, 1979-August 1979
- Hotplate method, colourimetry as previous method

4. Laboratory: Dorset lab, Dorset, August 1979-June 1, 1982
Sampling: Container - 500 ml or 1 L nalgene, acid/base bath, distilled water rinse
Field collection - as above
Analysis: August 1979-October 7, 1980
 - hotplate method, colourimetry by M.I.B.
 October 7, 1980-June 1, 1982
 - Block digestion method in a sulphuric acid-mercuric oxide-potassium sulphate media using 2 block digestors kept at 200°C and 360°C. The pH of the digestate is adjusted in-line. Ammonia is determined by formation of indophenol blue in a buffered system using nitroprusside as a catalyst.
5. Laboratory: Dorset lab, Dorset, June 1, 1982-June 4, 1984
Sampling: Container - 450 ml polystyrene with non-pulp lined cap
Field collection - as above
Analysis: As above
6. Laboratory: River lab, Toronto, June 4, 1984-present, in mg/L as N
Sampling: Container - as above
Field collection - as above
Analysis: As above

Oxygen

Identification: DO, mg/L as dissolved oxygen

Sample type: lake profiles

1. Laboratory: Dorset lab, Dorset, Sept. 1976-present
Sampling: Container - 125 ml prince of wales, with gas cap, unique pre-labelled bottle for each depth of each lake
Field collection - no rinsing of bottle, out-take pump hose placed at bottom of bottle and sample filled to overflowing, sealed gas free with cap, refrigeration until analysis
Analysis: Winkler titration method
2. Laboratory: Dorset lab, Dorset, April 1978-September 1978
Sampling: Container - as above
Field collection - as above
Analysis: Rexnord Model 350 Oxygen analyser, values recorded, but not reported

Sample type: streams

1. Laboratory: Dorset lab, Dorset, March 1982-May 1982
Sampling: Container - as above, unique bottle for each stream station
Field collection - both notch and pool samples taken, by submersing or decanting flowing water into bottle with minimal addition of bubbles, only pool values entered to data set
Analysis: Winkler titration method
2. Laboratory: Dorset lab, Dorset, May 1982-present
Sampling: Container - as above
Field collection - pool samples only
Analysis: As above

pH

Identification: pH

Sample type: streams, lakes (strata), precipitation

1. Laboratory: River lab, Toronto, June 1975-September 1976
Sampling: Container - 1 L Boston glass, new recycled every time
Field collection - 76 μ filter, triple rinse
Analysis: Measurement at room temperature, Corning meter with Corning or Fischer electrodes
2. Laboratory: Vankoughnet lab, June 1976-Sept. 1976, Dorset lab, Dorset, Oct. 1976-June 1978
Sampling: Container - 1 L nalgene, H₂SO₄ and NaOH bath with distilled water rinse
Field collection - as above
Analysis: As above
3. Laboratory: Dorset lab, Dorset, June 1978-June 1, 1982
Sampling: Container - as above
Field collection - as above
Analysis: Radiometer pH meter, Corning or Radiometer electrodes, analysis at room temperature
4. Laboratory: Dorset lab, Dorset, June 1, 1982-present
Sampling: Container - 250 ml opaque brown nalgene
Field collection - as above, field filtration discontinued after March 25, 1986.
Analysis: Simultaneous pH determination during ALKT and ALKTI titrations on semi-automated modular titration system with microcomputer control

Sample type: lake profiles

1. Laboratory: Dorset lab, Dorset, June 1978-present
Sampling: Container - 6 oz. prince of wales with screw-on gas cap, unique pre-labelled bottle for each depth for each lake
Field collection - rinse 3X with sample, filled to overflowing by inserting pump out-take hose to bottom of bottle
Analysis: Radiometer pH meter, Corning or Radiometer electrodes, analysis at room temperature

Phosphorus

Identification: PPFT (dissolved total phosphorus) in $\mu\text{g/L}$ as P

Sample type: streams, lakes, precipitation

1. Laboratory: River lab, Toronto, June 1975-summer, 1976
Sampling: Container - 1 L Boston glass
Field collection - 76 μ filter, triple rinse with sample
Analysis: Automated Stannous chloride with Blue Molybdate reduction with hotplate digestion, AAI system
2. Laboratory: Vankoughnet lab, summer 1976-fall 1976
Sampling: Container - 125 ml erlenmeyer flask, acid/base/distilled water washed, then heated in oven, sealed with parafilm
Field collection - as above
Analysis: As above
3. Laboratory: Dorset lab, Dorset, September 1976-March 31, 1979
Sampling: Container - 50 ml culture tubes, autoclaved
Field collection - 76 μ filter then Gelman filtration with .45 μ Sartorius millipore in the field, duplicates
Analysis: As above
4. Laboratory: Dorset lab, Dorset, March 31, 1979-March 20, 1981 (discontinued after that)
Sampling: Container - as above
Field collection - as above, triplicates, .45 μ filtration by chemistry lab after September 1979
Analysis: March 31, 1979-August 30, 1979
- Automated Ascorbic Acid Reduction - Molybdate colourimetry
September 1, 1979-March 20, 1981
- as above, with autoclave digestion method

Identification: PPUT (total phosphorus) in $\mu\text{g/L}$ as P

Sample type: streams, lakes, precipitation

1. Laboratory: River lab, Toronto, June 1975-March 1976
Sampling: Container - 1 L Boston glass
Field collection - 76 μ filter, triple rinse, refrigeration until analysis
Analysis: Automated Stannous chloride molybdate reduction, hotplate digestion with AAI system
2. Laboratory: Vankoughnet lab - Dorset lab, Dorset, March 1976-September 1976
Sampling: Container - 125 erlenmeyer flasks, acid/base/distilled water bathed, then oven heated, covered with parafilm

- Analysis: Field collection - as above
As above
3. Laboratory: Dorset lab, Dorset
Sampling: Container - September 1976-March 22, 1979, 50 ml pyrex culture tubes with Teflon-lined caps, autoclaved by chemistry lab
Field collection - as above, filled directly with station sample water, or poured from nutrient sample in the lab, after December 1979 triplicate samples were taken, prior to that duplicates were collected
- Analysis: As above
4. Laboratory: Dorset lab, Dorset, March 22, 1979-March 25, 1986
Sampling: Container - as above
Field collection - as above
Analysis: Automated ascorbic acid reduction, autoclave molybdate colourimetry
5. Laboratory: Dorset lab, Dorset, March 25, 1986-present
Sampling: Container - as above
Field Collection - duplicate samples submitted
Analysis: As above

Silicon-Reactive Silicates

Identification: SiO_3UR mg/L as SiO_2

Sample type: streams, lakes, precipitation

Laboratory: River lab, Toronto, June 1975-present

1. Sampling: Container - June 1975-January 1, 1982, 1 L Boston glass, new reground each sample
Field collection - 76 μ filter, triple rinse, refrigeration until analysis, no preservation
Analysis: Automated Molybdosilicate colourimetric method with AAI system, range .07-5.0 mg/L
2. Sampling: Container - January 1, 1982-June 1, 1982, 250 ml polystyrene with non-pulp lined plastic cap
Field collection - as above
Analysis: As above
3. Sampling: Container - June 1, 1982-present, 450 ml polystyrene, with non-pulp lined plastic cap
Field collection - as above
Analysis: June 1, 1982-July 1, 1983 - as above
4. Sampling: Container - as above
Field collection - as above
Analysis: July 1, 1983-April 1, 1986 - Fixed flow injection system introduced, no changes in analytical ranges
5. Sampling: Container - as above
Field Collection - as above
Analysis: April 1, 1986-present. Automated molybdosilicate colourimetric method with AAI system, range 0.02 - 10.0 mg/L

Sulphate

Identification SS04UR, mg/L as SO₄

Sample type: streams, lakes, precipitation

Laboratory: River lab, Toronto, June 1975-present

Precipitation lab, April 1, 1978-present

1. Sampling: Container - June 1, 1975-June 1, 1982, 1 L Boston glass

Field collection - 76 μ filter, triple rinse, no preservation

Analysis: June 1975-June 23, 1980, Methyl-thymol blue (MTB) colourimetric method, June 23, 1980-present, Automated suppressed ion chromatography

2. Sampling: Container - June 1, 1982-present - 450 ml polystyrene

Field collection - as above

Analysis: Automated suppressed ion chromatography

Trace Metals

Identification: CUUT (Copper) in mg/L
NIUT (Nickel) "
PBUT (Lead) "
COUT (Cobalt) "
CDUT (Cadmium) "
CRUT (Cromium) "
ASUT (Arsenic) "

Sample type: streams, lakes, precipitation

- Laboratory: ITC (Inorganic Trace Contaminants), Toronto
1. Sampling: Container - June 1975-May, 1978, 1 L acid washed nalgene by Central Stores
Field collection - 76 μ filter, triple rinse, fixed with 1.0 ml HNO_3 prior to submission, no refrigeration. Parameter groups submitted as one of the following:
- Zn*, Al*
- Cu, Ni, Zn, Al, Pb*
- Cu, Ni, Zn, Al, Pb, Co, Cd*, Cr, As
*see separate discussions for these parameters
Analysis: For Zn, Al, Cu, Ni, Pb, Co, Cd, Cr, all aqueous solutions were preconcentrated in 500 ml beakers and analyzed by flame AAS (test tubes replaced beakers during 1975-1982 resulting in greater precision). For As, analysis was by colourimetry with pyridine and silver diethyldithiocarbamate until 1975, then with Arsenazo III until 1978. Analysis now by hydride generation with borohydride and measurement by flameless AAS.
2. Sampling: Container - May, 1978-May, 1979 - 1 L acid washed nalgene stored with distilled water and 1 ml conc. HNO_3 . This solution was removed just prior to sampling.
Field collection - as above
Analysis: As above
3. Sampling: Container - May 1979-Sept 1, 1983 (lakes), Nov. 3, 1983 (precip), Jan. 6, 1984 (streams) - 500 ml acid washed nalgene
Field collection - as above
Analysis: May 1979-June 1982 as above
June 1982-April 1983, parameter groups requested:
a) Al, Zn, Cu, Ni, Pb - all aqueous solutions preconcentrated in 100 ml tubes, flame AAS or ICP finish depending on how busy each instrument was (both methods equivalent)
b) Cu, Ni, Zn, Pb, Co, Cd, Cr, As - all except As done as above but ICP finish due to number of elements requested. As done by hydride generation and AAS finish

4. Sampling: Container - Sept 1, 1983 (lakes), Nov. 3, 1983 (precip) and Jan 6, 1984 (streams) - March 20, 1985 - 450 ml polystyrene, non-pulp lined plastic cap.
- Field collection - as above. After Aug. 1984 some trace metals no longer requested for analysis. Al, Zn, Cd, Pb analyzed by Dorset after Nov. 18, 1985.
- Analysis: April, 1983-Aug. 1984, parameter groups requested
- a) Al - Dorset...see Aluminum section
 - b) Zn, Cu, Ni, Pb - as above...see Zinc, Lead section
 - c) Cu, Ni, Zn, Pb, Co, Cd, Cr, As - as above...see Cadmium section

Zinc

Identification: ZNUT in $\mu\text{g/L}$ or mg/L as Zn

Sample type: lakes, streams, precipitation

1. Laboratory: ITC, Toronto, June 1975-April 11, 1983
Sampling: Container - June 1975-June 1, 1982, 1 L nalgene, acid washed with HNO_3 by Central Stores, fixed with 1 ml HNO_3
- June 1, 1982-August 10, 1982, 250 ml polystyrene, rinsed and stored with 5% Hcl, fixed with 0.5 ml HNO_3
- August 10, 1982-April 11, 1983, 500 ml HNO_3 acid washed nalgene by Central Stores, fixed with 0.5 ml HNO_3
Field collection - 76 μ filter, triple rinse
Analysis: Aqueous solutions preconcentrated in 100 ml tubes, flame AAS or ICP finish
2. Laboratory: Dorset lab, Dorset, April 11, 1983-August 30, 1984
Sampling: Container - 15 ml polypropylene centrifuge tube with cap, pre-leached in 1% concentrated HNO_3 then rinsed four times with double de-ionized water
Field collection - as above
Analysis: Flame atomic absorption spectrophotometry

Sample type: precipitation, multistation streams, Harp streams

1. Laboratory: Dorset lab, Dorset, November 18, 1985-present
Sampling: Container - 500 ml or 1 L nalgene, pre-acid rinsed and bagged
Field collection - as above
Analysis: Samples are opened under clean air and acidified to 0.2% with 2 ml Superpure Nitric Acid. Analysis by Anodic Stripping Voltammetry (ASV) in $\mu\text{g/L}$.

v) Quality Assurance

The quality assurance management programme has been outlined in a recent O.M.E. publication (Locke, 1985). The objectives, organization and responsibility of the Limnology Section's programme are described in that report. An extensive replicate quality control study was undertaken from 1983-1985 for the lake, stream and precipitation chemical sampling. The results of these detailed QC analysis will be available in an upcoming report (Locke, in prep.).

Quality control checks form a routine part for all sampling programmes at the Dorset Research Centre. Regular QC samples are scheduled as outlined in Table 9. Additional QC checks on sample containers and sampling devices are run on a routine or as-need basis. A record is kept of all equipment calibration and maintenance. Field data log books are all kept current and on file. These records are used as a source of reference and as a quality control check to ensure that sampling methodology uniformity is maintained.

Data integrity is maintained by a rigorous set of edit procedures that are applied throughout all facets of the study. These procedures are outlined in detail in the upcoming QC data report (Locke, in prep.).

Table 9: QC Sampling Schedule

	<u>Dorset parameters</u>	<u>Toronto parameters</u>
	nutrients pH/alk	major ions trace metals
lakes	. 1983 - lakes sampled with 5 replicates on a rotating station and parameter schedule (May-Nov.)	
streams		
precip	. 1984 - all parameters sampled as 5 replicates on a rotating station and parameter basis (May-Dec.)	
	. 1985 - selected parameters (by precision error analysis) sampled as 5 replicates on a rotating station basis	
	. 1986 - further error analysis will lead to selective parameter and station replication	
	. QC precision error analysis available in upcoming report (Locke, in prep.)	

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